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Contents


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CONTENTS

(Continued on the next page.)

ON THE POSSIBILITY OF AN ENTIRELY EXTRACRANIAL VISUAL PROSTHESIS*

Latif Morkos Cozman

Following the discovery by Forster in 1929 and Krause and Shum in 1931 that the electrical stimulation of a point on the surface of the visual cortex caused a blind subject to see a point of white light in a particular place in the visual field; that the stimulation of a different point of this cortex caused the perception of another point of light in a different place in the visual field; the possibility of an electronic visual prosthesis emerged based upon a miniaturized TV camera capable of transforming light and dark picture elements into discrete electric currents corresponding to them.

A television system involving the use of the human brain itself should not be attempted until it is sure that no possible harm would be caused. Present research involves the introduction of thousands of microelectrodes in contact with the visual cortex.

Not surprisingly, prudent neurologists and intelligent patients might well have serious reservations about the procedure. It might have surfaced regarding hearing aids if an extracranial deaf aid did not exist and so much as a single electrode was proposed to be introduced in contact with the auditory cortex. Virtually no one would have accepted such a hearing aid, even though its construction might be very much more simple than a visual aid.

When a path taken by research is seen to be leading toward an undesired application, it is useful to explore the reasons for our disappointment, and to seek other means of overcoming the difficulties. Despite the disfavor with which the idea has met, the stimulation of the visual cortex via extracranial electrodes to an *intact* brain is a possibility that should be thoroughly investigated before being ruled out.

We deal here with some possibilities of stimulating the visual cortex from extracranial electrodes, and also with an arrangement for eliminating the need for a scanning procedure; these eliminate the intracranial implant, with its multiple wires or channels, and the elimination of the scanner itself.

ELIMINATION OF SCANNING

The scanning procedure was developed out of its role in transmitting and receiving facsimile and TV images. However, it is not necessary to imagine that scanning should be necessary in cases where radio or wire links are not used (as for example in transmitting pictures in photography, microscopy, and ordinary telescopy). In these cases, all the picture elements are transmitted optically and reproduced simultaneously. In a visual prosthesis each picture element has to be transformed into a minute electric current, and discrete electric currents can be acted upon by suitable electrostatic lines of force (an ES lens), and by suitable magnetic lines of force (an EM lens), to maintain their flow (with an ES

*Paper presented to the University of Alexandria, Egypt, April 3, 1974.

lens) in parallel directions. Thus, the possibility exists of dropping out the scanning procedure with all its disadvantages in a visual prosthesis. This would very much simplify the required miniature TV camera. Mention will be made below of how the minute electric currents resulting from the transformation of the light and dark of the image's picture elements could be separated from each other and constrained to follow parallel paths until they impinge on different points of the visual cortex.

Figure 1 illustrates that numerous signals can flow simultaneously in parallel paths through a dilute aqueous solution of cerebrospinal fluid (such as that inside the brain and nerve cells).

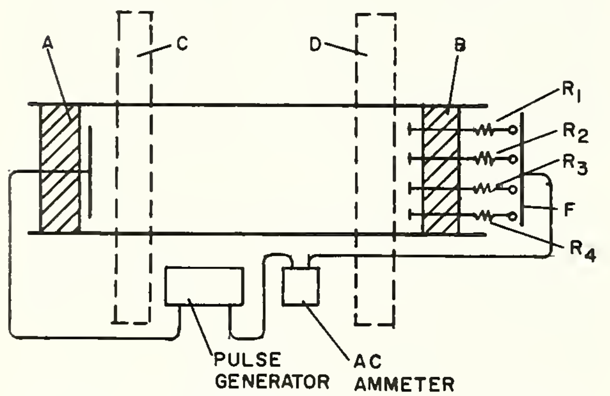

Figure 1. Simultaneous Signal Flow in Parallel Paths Through a Dilute Aqueous Solution of Cerebro-Spinal Fluid.

Glass stopper *A* closes one end of a glass tube, with a platinum disk firmly attached to the inner surface. Stopper *B* closes the other end. Instead of a solid platinum disk, it has on its inner surface a similar disk that has been cut into a large number of separate platinum strips, to each of which is attached a metal wire, a resistor, and a socket that connects the path to a conducting disk *F* if the pin is put inside the socket. Either one or more of the strips on *B* can be put into circuit by putting the pins in the respective sockets. The resistors R_1, R_2, R_3, R_4, etc. may differ in their ohmic values, and their insertion makes the voltages at the various strips in *B* differ, a situation that will arise in the visual device to be shown. *C* and *D* are two coaxial coils of wire through which direct current in the correct direction passes, the aim being the generation of an axial magnetic field. Between the two stoppers is a dilute solution of sodium chloride. A pulse generator and an ac ammeter complete the circuit.

To begin, one single strip in *B* is connected into the circuit by inserting a pin in its socket. The rectified current is read on the ammeter after switching on the pulse generator. Then the experiment is repeated for 2, 3, 4. . . *n* strips connected together in circuit. It will be seen that the ammeter registers in every case a current that is equal (to a very near approximation) to the current for one strip, multiplied by the number of strips of *B* in connection with the circuit. This could never be the case unless the currents in the weak electrolyte solution followed parallel paths. For this reason, when a strip is dropped out, the current for it disappears. It should be noted that the whole disc in *A* and the numerous strips in *B* form parallel plate condensers, the lines of force between which would be parallel, particularly when aided by the axial magnetic field. Thus, we are actually using an electrostatic lens combined with a magnetic lens.

EXTRACRANIAL ELECTRODES

Figure 2 shows the position of the head, the converging lens, the TV camera 5, 1, and the extracranial electrodes 5 and 7. When 5 is positive, 7 is minus and vice versa. Thus, the curved lines shown at the bottom of Fig. 2 may represent the electrostatic field. They can represent, however, the magnetic field by inserting a magnetic North pole at 5, a magnetic South pole at 7, a magnetic North pole at 8 and a magnetic South pole at 9, see Fig. 3. By adjusting the positions of 8 and 9, the EM will coincide with the ES field.

It should be noted that the reason for adopting the positions shown in Fig. 2 is to confine the passage of currents through the visual cortex, the area connected with vision. Installing electrode 5 directly on the forehead (in a position parallel to electrode 7) would entail the

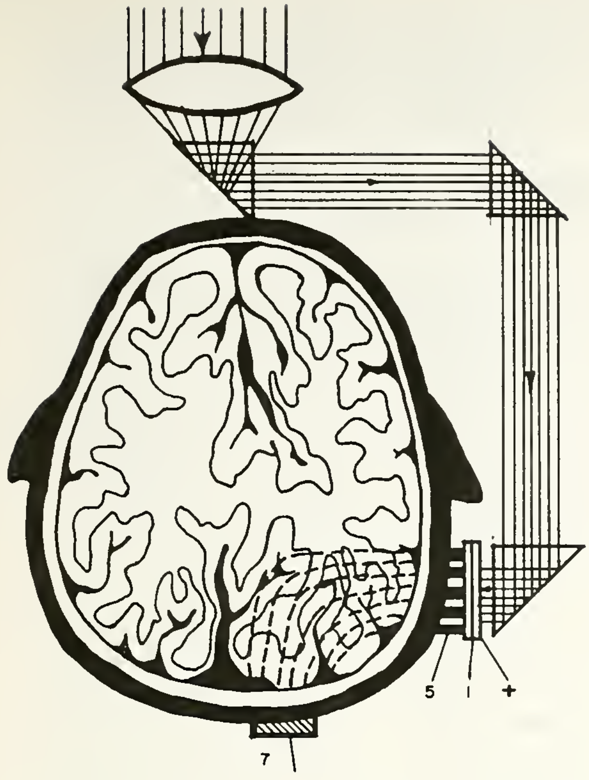

Figure 2. Position of Head, Converging Lens, TV Camera, and Extracranial Electrodes.

injury resulting from a disharmony with the normal electrical activity of these areas.

The latest research in neurophysiology and electroencephalography has paved the way for fulfilling these requirements in the most efficient way.

But first, let us describe a miniature TV camera suitable for a non-scanning extracranial-electrode device. In Fig. 4, a conductive glass disk, 1, in addition to being transparent to light rays, passing them to a photoconductive semiconductor layer, 2, on its back surface, puts layer 2 in electrical contact with the high voltage supply *HT*.

Layer 2 is in touch with a first mosaic, 3, consisting of a very large number of very minute conducting glass slabs or elements, arranged in checkerboard fashion, with horizontal and vertical insulating thin linings separating them in a uniform way. A second mosaic, 5, of conductive glass slabs, similar in all respects to the first mosaic, 3, is transparent to visible rays falling on it from electric lamp bulbs, 6, and also serves

passage of current through other areas as well, where stimulation of motor or sensorimotor centers is possible, in addition to a much longer electrical path as compared with that in Fig. 2.

It would appear that by employing intracranial electrodes to contact the visual cortex we can avoid the passage of currents through the brain. But the electrical circuit must be completed by using a bus electrode, whether intracranial or extracranial.

Thus, since there can be no escape from currents through the brain, they must be carefully chosen so that:

1. No stimulation of the motor or sensorimotor centers is elicited that might result in convulsions or epileptic effects;

2. Current density is low enough to avoid excessive heat generation in the brain that might cause unconsciousness or sleep; or any

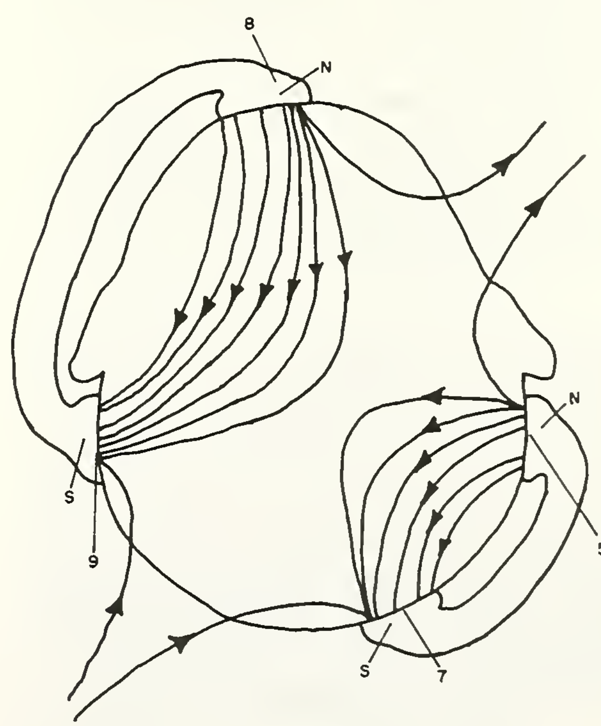

Figure 3. The Magnetic Field

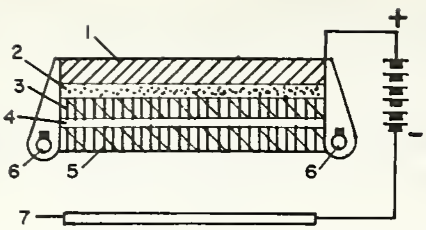

Figure 4. Schematic of Miniature TV Camera for Non-scanning Device.

as the return path to the *HT* of the source of current. Between the first mosaic, 3, and the second mosaic, 5, is a very thin layer, 4, of colloidal graphite crystals suspended in an insulating medium, such as thin mineral oil. The second mosaic, 5, consists of tiny slabs of conducting glass in an arrangement which is in exact symmetry with the tiny slabs of the first slab, 3, in checkerboard pattern with horizontal and vertical insulating thin linings, each slab in the mosaic, 5, being opposite to a corresponding slab in mosaic, 3. The mosaic, 5, forms the border of the device furthermost from the impinging light and the conductive disk, 1, and is maintained in good electrical contact with the scalp in a position as near as possible to the occipital lobe of one hemisphere (Figs. 2 and 3).

The second mosaic, 5, is not connected directly to *HT*, for the latter is connected to an electrode, 7, in contact with the scalp in a position opposite the space between the two hemispheres (Figs. 2 and 3).

As in the ordinary vidicon, the surface of layer 2 furthest from layer 1, will have built on to it an electrical image of potential differences that corresponds to the light and dark areas of the optical image, and because conductive glass, 3, and the conductive slabs in 5 form a composite parallel plate condenser with parallel lines of force, the colloidal graphite crystals in 4 will tend to orient in the same direction; because the graphite conducts, parallel and discrete currents of electricity* will reach 5 because of the presence of the insulating linings in 3 and 5.

*UK Patent No. 1172412, British Patent Office, 25 Southampton Buildings, London, WC2, England.

The ES field referred to above between 3 and 5, and the employment of an EM field coinciding with it (Fig. 3) is achieved with the aid of appropriate magnetic poles.

ELECTROPHYSIOLOGY IN SERVICE OF THE BLIND

Electrophysiology, and particularly electroencephalography, have revealed many significant facts about the brain which, unfortunately, have not been coordinated so as to furnish the best understanding of the electrophysiology of vision--an understanding that must be established before the difficulties of building a scanless extracranial electrode prosthesis can be overcome. How can the most efficient means of transmitting electric current through the brain be found if the true electrical activity of the brain cells is not known? It is no longer sufficient to regard a brain cell as a wet battery generating about 0.1 volt, because this is only partially true. More useful is the concept that there are brain cells like those in the visual cortex that function as tuned or tunable electrical circuits which either oscillate, giving rise to the dominant or alpha brain rhythm of about 10-per-second, or propagate this frequency most efficiently as a consequence of resonance. These notions yield to further elaboration when compared with some of the basic references in the field. Based on the literature, the following comments and elaboration illustrate the approach:

1. In 1934, E. D. Adrian and B. H. C. Matthews showed that alpha rhythms could indeed be driven by repetitive flash stimuli. This is an instance of resonance wherein oscillation at a certain frequency induced the same oscillation in a circuit tunable to the same frequency (Walter, 1965, p. 97).

2. Visual sensations were elicited from the occipital lobes (Walter, 1965, p. 56).

3. Adrian and Matthews proved that the alpha rhythm arises in the visual association areas of the occipitus (Walter, 1965, p. 56).

4. The occipital alpha rhythms arising in the visual area of the cortex are as a rule absent or faint in the blind (Babsky, Khodorof, Kositsky, and Zubkov, 1970, p. 277). This is a most significant observation, and if considered in conjunction with the known fact that the stimuli transmitted to the brain are in the form of individual groups or "volleys," the amplitude and duration of the individual impulses identical but differing in frequency, the whole visual process must be based on the alpha rhythm--its production and transmission from the retina to the visual cortex. In other words, the neurones in the optic nerve and in the visual cortex are fundamentally tuned to the frequency of the alpha rhythm. This is in agreement with what physiologists have reiterated, namely that the nerve fibre is a chain of relay stations, many stations to the inch, constantly regenerating the signal. Before the present instance, however, no one has referred to the tunable nature of the brain cell, and its amenity to resonance as the relaying principle.

5. Realizing that the brain cells act as tuned circuits, it is easy to understand why "The 19th Century raised its poetic eyebrows at nature's prodigality. The 20th Century is no less surprised by the economy of structure and function discovered in the mechanics of life." (Walter, 1965, p. 113.) In the proposed prosthesis the aim is toward a similar high efficiency, and one should not be content with what is good enough in the electrolysis of water, for example, in the migration of the positive cation to the cathode and the negative anion to the anode. In other words, we must not ignore the brain cells.

6. Many cells of the central nervous system possess *automatism*, that is they generate rhythmic impulses even in the absence of external stimuli. Constant slow fluctuations of the membrane potential, accompanied with isolated or multiple discharges of action potential occurring when the membrane has been depolarized to a certain cortical level can be observed in these cells. The arrival of nerve impulses at such an automatically discharging cell leads to an increase in membrane depolarization, and consequently to a heightening of the frequence of impulse discharge. (Babsky, et al., p. 96.) This rise of frequency of the oscillation produced by nerve cells on the start or stopping of impulse trains has detracted from their property of tuning, and that is why this writer refers to them as "tunable." However, this frequency rise is of paramount importance in the visual process. Within 0.1 to 0.5 second of illuminating the eye, the arriving impulses rise in frequency from the alpha frequency of approximately 10-per-second to a very high frequency; resonance with the brain cells suffers, and "visual sensation disappears when the eyes are immobile." (Babsky, et al., p. 201.) "During the continuous action of light on a visual receptor impulses quickly cease in the corresponding fibres of the optic nerve and this shows the important role of eye movements in the visual process." (Babsky, et al., p. 201.) "Yarbus found that the eye, in looking at any object, made incessant imperceptible jumps. As a result the retinal image was continually displaced from one point to another so producing new impulses in the ganglion cells and the nerve fibres leading from them." (Babsky, et al., p. 201.)

7. Spontaneous activity is closely akin to evoked activity, since it is not possible to distinguish in the records between the unit spikes or slow wave in either. (Davson and Eggleton, 1962, p. 1020.) Thanks to this principle, artificial stimulation of the visual cortex, if undertaken with due consideration to efficiency and other requirements, will provide a benign prosthesis.

8. Activity in individual neurones seemed to be propagated as a traveling wave from one part of the cortex to another. (Davson and Eggleton, 1962, p. 1021.) A traveling wave through a medium,

like the transverse waves on the surface of water, implies that the frequency of the wave is the same as the frequency of the various particles or components reached successively by the wave; another bit of evidence in favor of the primacy of the alpha-rhythm frequency in the brain cell!

From these last two points it will be seen that if electrical impulses having the frequency of the alpha rhythm are made to act on some cells of the visual cortex, they would propagate in the direction determined by the electrostatic and magnetic fields arranged as to focus the wave.

Other evidence relating to the linkage of alpha rhythms and vision exists:

1. Although it is sometimes said that alpha rhythms cease when the eyes are opened, or a mental pattern is seen, or when one indulges in visual imagery, more accurate observation shows that such waves do not cease upon the arrival of visual impulses, since this occurs after a relatively long period. Alpha rhythms are reestablished when the eyes are opened, provided the retinas are uniformly stimulated. If, however, the subject tries to fix objects in the visual field, the alpha rhythms are blocked.

2. Absence of alpha rhythms in adults is normally a sign of vivid visual imagination.

3. Individuals with persistent alpha rhythms which are hard to block with mental effort tend to auditory, kinaesthetic, or tactile perception rather than visual imagery. In these cases the alpha rhythms continue even when the eyes are open and the mind is active or alert.

Strangely enough, nobody has ever attempted to synthesize larger constructs on these grounds. The author suggests, however, that the alpha rhythms:

1. Are blocked when an image is perceived because such a process needs energy which the alpha rhythms supply.

2. In persons in whose EEG records there are no alpha rhythms, these rhythms are consumed in vivid visual imagination.

3. In persons with persistent alpha rhythms these rhythms are not consumed because the energy needed is supplied by means of auditory, kinaesthetic, and tactile imagery.

The inference is that alpha rhythms in all three cases are essential for vision and visual imagination; that is why they are not blocked when the subject is dependent on perception other than visual.

In sum, we have attempted to show, through appropriate correlation of the functions of alpha rhythms and the characteristics of brain cells that it is possible to build up a very simple visual prosthesis using an *intact* skull and brain, without the need for scanning devices, by stimulating the visual cortex from extracranial electrodes via impulses at alpha-rhythm frequency, by guiding the path of the discrete currents produced by the scanless TV camera employed, through shaping provided by electrostatic and electromagnetic fields.

Comments on the analysis would be welcomed.

REFERENCES

Babsky, E. B., Khodorof, B. I., Kositsky, G. I., & Zubkov, A. A. *Human physiology.* Volume 2. Moscow: MIR Publishers, 1970.

Bell, George H., Davidson, G. Norman, & Scarborough, H. *Textbook of physiology and biochemistry.* Edinburgh: E. S. Livingstone, 1961.

Davson, H., & Eggleton, G. *Principles of human physiology.* London: J. A. Churchill, 1962.

Talaat, M., Hamdi, H., Gabrawi, B. G., Abdel-Rahman, U. *Talaat's Physiology.* Volume 4. Cairo: 1971.

Walter, W. G. *The living brain.* New York: Penguin Books, Pelican Edition, 1965.

A METHOD FOR THE COMPARATIVE EVALUATION OF VISUAL AND AUDITORY DISPLAYS

P. W. Davall and J. M. Gill*

Abstract: In reading and mobility aids for the blind it is desirable to design the display to optimize the man-machine interface. This paper describes a possible method for comparing various displays.

Five subjects used compensatory tracking with random input signals (five different cutoff frequencies) with five one-dimensional displays where the error is represented by: 1) Visual: deflection, 2) Auditory: mark-space ratio, 3) Auditory: matching frequency, 4) Auditory: beat frequency, 5) Auditory: amplitude matching.

The significance of the coherency between the input signal and the subjects' output is discussed. The measured closed-loop frequency response is compared to that obtained from a modified form of cross-over model. Finally, two performance parameters are proposed for assessing the various displays.

INTRODUCTION

Research on the design of auditory displays has usually been motivated by the desire to provide nonvisual displays for those who cannot use vision or to supplement a visual display particularly in aeronautical applications.

Pollack and Ficks (1954) studied multi-dimensional auditory displays in which each variable had only two states. They found that, in general, multiple stimulus encoding is a satisfactory procedure for increasing the information transmission rate associated with such displays. Mudd (1965) studied the relative effectiveness of frequency, intensity, duration and interaural difference dimensions of a pure-tone binary display. Frequency proved to be the most effective dimension for the purposes of cueing; intensity was the least effective.

Roffler and Butler (1968a) found that listeners could locate auditory stimuli accurately in the vertical plane when the stimulus was complex and included frequencies above 7kHz. Roffler and Butler (1968b) then found that subjects tended to place the audio stimuli on a vertical scale in accordance with their respective pitch. Higher-pitched sounds were perceived as originating above lower-pitched sounds.

Vinje and Pitkin (1971) studied human operator dynamics for aural-compensatory tracking using pitch of the tone to represent the magnitude of the tracking error. Error polarity was indicated in the two-ear display by switching the tone between ears as a function of error sign. For the one-ear display, error polarity was indicated by using modulated and unmodulated tones. The describing function and remnant data indicated that humans can control as well with aural cues as with visual cues for input signals with cutoff frequencies of 0.27 to 0.56 Hz.

A variety of two-dimensional auditory displays have been built. For instance, Black (1968) developed

*Department of Engineering, University of Warwick, Coventry CV4 7AL, England.

a display where the horizontal coordinate was represented by time delay and amplitude of the signal and the vertical coordinate by frequency (100-400 Hz). Fish and Beschle (1973) also used frequency (200-7000 Hz) for representing the vertical position of the scan but interaural intensity differences (up to 40 dB) for the horizontal.

Phillips and Seligman (1974) developed a multi-dimensional auditory display in which frequency, amplitude and timbre are all utilized. Robinson (Gill, 1974) also developed a two-dimensional display, as a non-visual equivalent to the cathode-ray oscilloscope, where the frequency of the signal depends on the vertical coordinate and time delay for the horizontal. However, there has been little systematic comparison of the various types of auditory displays, even though Kramer (1962) mentioned the need for this over a decade ago.

This paper describes a method for comparing various displays and applies the technique to one visual and four auditory one-dimensional displays. The technique can be extended to multi-dimensional displays.

EXPERIMENTAL METHOD AND ANALYSIS

The human operator was presented with an error signal $e(t)$, which was the difference between the input, $x(t)$, and the output, $y(t)$, (Fig. 1). The output was measured from two strain gauges (making two arms of a bridge section) strapped across a stiff joystick. The choice of a force (as opposed to a position) joystick considerably reduced the response time delay introduced by the muscle motor action of the arm. The input, $x(t)$, was band-limited gaussian white noise. Five bandwidths of 0.3, 0.5, 0.7, 1.0, and 1.5 Hz were used for each form of error-signal

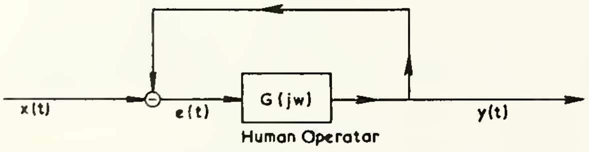

Figure 1. Closed-loop Configuration for Human Operator Tracking Tests.

presentation. The operators' task was to minimize the error.

Error Signal Presentation

<u>Visual feedback</u>. A horizontal line on a cathode-ray tube display moved vertically about a center zero, the deflection being a function of the error signal. By pushing on the joystick the line was moved up the screen, while pulling brought the line down. Full scale deflection was ±10 cm in response to an error signal of ±10 volts (0.5 kg-per-volt).

<u>Mark-space audio feedback</u>. The error signal was presented as short bursts of a single tone. Pulling the joystick reduced the duration of the pulses and increased the silent periods, while pushing reversed the effect. The fundamental clocking period for repeating the pulses was 0.15 seconds (Fig. 2). The zero error state was defined as unity mark-space ratio between noise and silence.

<u>Matching-frequency feedback</u>. A 1-kHz square was fed to the left ear as a reference tone while a variable-frequency square wave of equal amplitude was fed to the right ear. The frequency of the variable signal was controlled by the joystick, and could vary from zero to 3 kHz for full-scale error deflection of -10 volts to +10 volts. Zero error was recorded when the two inputs were of matching frequency.

<u>Beat-frequency feedback</u>. The signal inputs were the same as those in "Matching-frequency feedback" (above), except that both inputs were presented to both ears simultaneously. The effect was different, however, in that signals of *three* frequencies could be heard; a beat frequency was present as well as the two fundamental frequencies. The beat frequency decreases as the two fundamental frequencies come closer

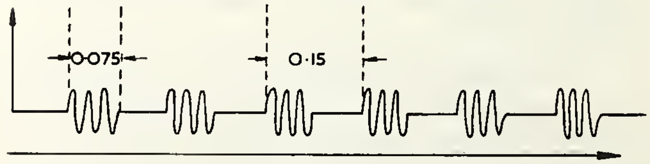

Figure 2. Zero Error State for Mark-Space Audio Feedback Error-Signal Presentation.

together. The advantage of this form of frequency matching is that it does not require the operator to be tone sensitive.

Amplitude-matching feedback. A 1-kHz square wave was presented to both ears. The amplitude presented to each ear as a function of the error signal is shown in Fig. 3. The loudness of the tone presented in each ear was approximately a linear function of the error (the ear being a logarithmic device to a first approximation). Zero error was recorded when the amplitudes were matched.

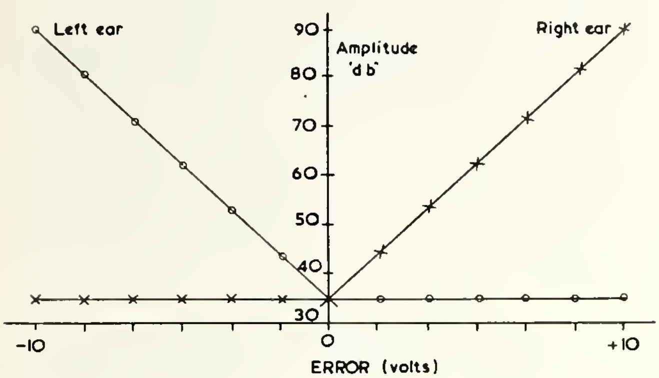

Figure 3. Amplitude V-Error Function for Left and Right Ears for the Amplitude-Matching Audio Test.

Analysis

$x(t)$: signal input

$y(t)$: system output

$e(t)$: error signal, $x(t)-y(t)$

$\hat{x}_i(j\omega)$: ith short-term Fourier estimator of $x(j\omega)$ at frequency ω.

$\bar{H}(j\omega)$: frequency-response estimate relating $x(j\omega)$ to $y(j\omega)$ at frequency ω.

$\bar{G}(j\omega)$: open-loop frequency-response estimate relating $e(j\omega)$ to $y(j\omega)$ at frequency ω.

$\bar{\phi}_{xx}(\omega)$: estimate of the auto-spectrum of $x(t)$ at frequency ω.

$\bar{\phi}_{xy}(j\omega)$: estimate of the cross-spectrum between x and y at frequency ω.

$\overline{C^2}_{xy}(\omega)$: squared-coherency estimate between x and y at frequency ω.

The signals $x(t)$, $y(t)$ and $e(t)$ were sampled five-times-per-second. Approximately ten-minute records were taken for each type of input signal (0.3, 0.5, 0.7, 1.0 and 1.5 Hz-cutoff frequencies.

The sample records were divided into blocks of N points (128 in this case) for Fourier analysis using a radix '2' fast Fourier algorithm (Blackman and Tukey, 1958; Wellstead, 1971) producing N/2 spectral coefficients over the frequency range 0 - 2.5 Hz. Approximately 30 short-term estimates of $e(j\omega)$, $x(j\omega)$ and $y(j\omega)$ were obtained for each input cutoff frequency.

$$\hat{x}_i(j\omega) = \sum_{k=0}^{N-1} x_t^i(k) \exp(-j\omega k) \qquad (1)$$

where k denotes the kth time sample in the ith block and for $\omega = 0.039$. L $0<L<N/2$ where 0.039 is the frequency resolution in Hertz. Similar expressions are used to calculate $\hat{y}_i(j\omega)$ and $\hat{e}_i(j\omega)$.

The overall closed-loop frequency response as estimated between $x(t)$ and $y(t)$ was calculated as follows:

$$\bar{H}(j\omega) = \frac{\bar{\phi}_{xv}(j\omega}{\bar{\phi}_{xx}(j\omega)} \qquad (2)$$

and the human-operator frequency response (open loop) relating $e(t)$ and $y(t)$ is given by:

$$\bar{G}(j\omega) = \frac{\bar{\phi}_{xy}(j\omega)}{\bar{\phi}_{xe}(j\omega)} \qquad (3)$$

where

$$\bar{\phi}_{xx}(j\omega) = \sum_{i=1}^{30} \hat{x}_i(j\omega)^*\hat{x}_i(j\omega) \qquad (4)$$

$$\bar{\phi}_{xy}(j\omega) = \sum_{i=1}^{30} \hat{x}_i(j\omega)*\hat{y}_i(j\omega) \quad (5)$$

$$\bar{\phi}_{xe}(j\omega) = \sum_{i=1}^{30} \hat{x}_i(j\omega)*\hat{e}_i(j\omega) \quad (6)$$

where * denotes the complex conjugate.

Modelling the human operator response. For each test, mean estimates of $\bar{H}(j\omega)$ and $\bar{G}(j\omega)$ were obtained. These represented the average performance over each ten-minute test. A linear model of the human operator, similar to the more complex cross-over models (Young, 1969; Krendel, McRuer and Graham, 1966), was used:

$$G_H(j\omega) = \frac{K\, e^{-j\omega\tau}\,(1+j\omega T_D)}{(c+j\omega)\,(1+j\omega T_s)\,(1+j\omega T_L)} \quad (7)$$

where K : an arbitrary gain factor which can be varied over a large range by the operator.

τ : human operator's response-time delay.

T_D : a velocity-lead response reacting to the rate of change in the error signal. The degree of velocity control exhibited is found to be dependent on the frequency content of the input.

c : a measure of the integral action of the operator. c is small when the operator is able to track slowly varying trends in the mean level of the error signal.

T_s: a low-pass element modeling the operator's ability to disregard high-frequency content in the error signal which may be due to his own reaction-time delay acting in a closed-loop mode.

T_L : a fixed low-pass element measuring the inability of the muscles to respond to frequency changes ($T_L = 0.04$, cutoff about 4 Hz).

The parameters of interest are τ (the reaction time delay), T_D (the operator's ability to react not only to the magnitude of the error but also to the manner in which it is changing) and c (a measure of the operator's ability to follow the mean level of the signal accurately). A Powell hill-climb routine (Fletcher and Powell, 1963) was implemented to model the responses obtained for $\bar{G}(j\omega)$ and $\bar{H}(j\omega)$ in each test in terms of a human operator model described in equation (7). The fixed low-pass element T_L was chosen to achieve a cutoff at about 5 Hz while T_s, the stability factor, was only allowed to operate on high-frequency cutoff tests. This is consistent with experience in that no stability problems were encountered in low-frequency tests. Thus the Powell hill-climb routine was allowed to optimize the parameters K, τ, T_D and c. The gain factor K acts in choosing the magnitude of the human operator's open-loop characteristic response. The limits imposed on K are physical limitations and not of direct interest to his mode of response. The restrictions on the values assumed by τ, T_D and c were taken from previous results, and from trial and error. The following limits were chosen:

$$0.1 \leqslant K \leqslant 20.0$$
$$0.1 \leqslant \tau \leqslant 0.6$$
$$0.0 \leqslant c \leqslant 1.0$$
$$0.0 \leqslant T_D \leqslant 4.0$$

and where applicable:

$$0.0 \leqslant T_s \leqslant 0.3$$

Response evaluation. The concept of a measure of "goodness" for a particular form of error signal presentation is subjective to a degree. However, for specific tasks such as continuous tracking and control tasks, two parameters may be considered to give a measure of the performance of one form of display against another.

The ideal operator response is achieved when y(t) follows x(t) exactly. Under these conditions the magnitude of the closed-loop frequency response is unity over all frequencies of interest. Deviations from this unity gain represent a loss. Thus a factor given by:

$$G_{FACT} = \frac{1}{F_{MAX}} \int_0^{F_{MAX}} \left| |\bar{H}(j\omega)| - 1.0 \right| d\omega \quad (8)$$

gives a number by which the gain response is characterized. F_{MAX} is chosen as some maximum frequency of interest for which the display is to be used. Each operator's response can thus be characterized by a factor G_{FACT}. The greater G_{FACT} the greater the overall deviation from the ideal response.

The amplitude of the overall response does not completely characterize the response. Phase shifts in the response can also be detrimental to the performance of a particular form of error signal presentation. The ideal phase characteristics are again zero-phase shift over all frequencies of interest. Thus a phase "goodness" parameter is proposed:

$$P_{FACT} = \frac{1}{F_{MAX}} \int_0^{F_{MAX}} | \theta_H(j\omega) | \, d\omega \quad (9)$$

where $\theta_H(j\omega)$ is the phase shift, in radians, of the closed-loop response $\bar{H}(j\omega)$. F_{MAX} is chosen as before.

Thus each operator's response to a particular form of error-signal presentation is characterized by two "goodness" parameters. The display which minimizes these two parameters can be judged to give the best response. However, for individual applications, the weight placed on the amplitude factor as opposed to the phase factor is a matter of choice.

RESULTS AND DISCUSSION

In assessing the operator's performance the coherency between the input and the operator's output presents a measure of the extent to which his output (at a given frequency) resulted as a direct response (albeit perhaps a wrong one) to the input. It is defined:

$$C^2_{xy}(j\omega) = \frac{\phi^2_{xy}(j\omega)}{\phi_{xx}(\omega) \cdot \phi_{yy}(\omega)} \quad (10)$$

at frequency where $0 \leq C^2_{xy} \leq 1$.

When the coherency equals one, the output can be defined exactly as a linear function of the input. When the coherency is zero the output is uncorrelated with the input.

Figures 4 and 5 show the mean-coherency squares results measured for two operators. The mean coherency was taken over the frequency range zero to cutoff for each test, and the results for each type of error-signal presentation and for each input cutoff frequency are displayed. Figure 4 was typical of results obtained for four of the five operators tested. The Visual Test showed a high level of coherency over the complete range of inputs used. The spread being typically $0.6 \leq C^2_{xy} \leq 0.95$.

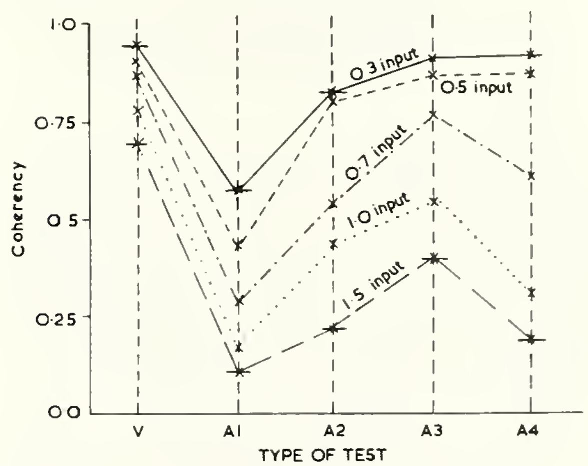

Figure 4. Mean-Coherency Level Obtained for a Single Operator for Each Form of Display and at Each Input Cutoff Frequency.

(The Mean Level is Taken Over the Frequency-Range O Cutoff)

Operator No. 2:

V - Visual
A1 - Mark Space Matching
A2 - Matching Frequency
A3 - Doppler Matching Frequency
A4 - Amplitude Matching

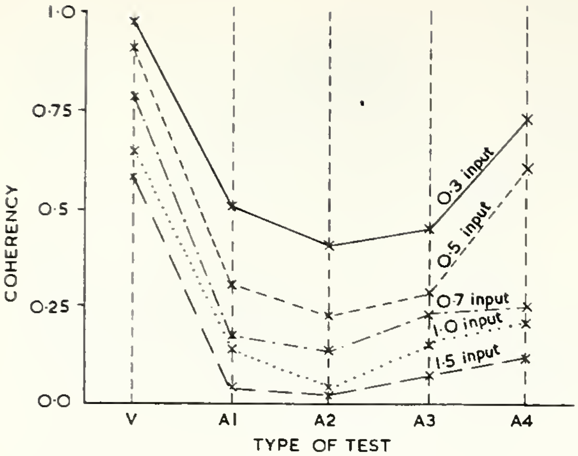

Figure 5. Mean-Coherency Level Obtained for a Single Operator for Each Form of Display and at Each Input Cutoff Frequency.

(The Mean Level is Taken Over the Frequency-Range 0 Cutoff)

Operator No. 2:

V - Visual
A1 - Mark Space Matching
A2 - Matching Frequency
A3 - Doppler Matching Frequency
A4 - Amplitude Matching

The results for the Mark Space Test (A1) show a low level of coherency on all tests. As the input cutoff frequency increases the operator is less able to track correctly and the coherency falls. Indeed it is doubtful whether the very high-frequency tests (1.0- and 1.5-Hz cutoff) can be tracked at all using the mark-space ratio feedback.

The Matching Frequency Test (A2) shows an overall improvement on the Mark Space Test, while Beat Frequency Feedback (A3) is probably the best display used over the frequency ranges of interest. It must be noted that although Amplitude Matching (A4) performed well for low-frequency inputs (slightly better even than A3), the operators found greater difficulty in matching amplitudes quickly than in matching frequencies.

Figure 5 shows the exception to the rule. For this operator the Amplitude Matching Tests results were consistently better than either frequency test. This is possibly explained by the hearing defect shown in the operator's audiogram (Fig. 6). However the case is made that an audio display must be tailored to suit the individual.

Closed-loop frequency response. Figure 7 shows the closed-loop frequency response results as measured at each input cutoff frequency for each type of error signal presentation. The results are shown for a single operator.

At low-input cutoff frequencies the closed-loop gain response is approximately flat and approaching unity while the phase response shows the phase shift slowly increasing with frequency. The ideal response is defined as unity gain over all frequencies with zero-phase shift. As the input cutoff frequency increases the gain response decreases sharply, with unity gain only occurring at very low frequencies. The rate of increase in phase shift is greater than expected by extrapolation of the low-frequency results. Thus, in general, the operator changes his mode of operation as the input cutoff frequency increases. In some cases, the inherent time delay in the operator's response leads to a resonant peak in the closed-loop response.

In measuring the operator's response it must be recognized that his response will change as his concentration and skill vary. For this reason, untrained operators were used to try to nullify any skill discrepancies in the results. Possibly a

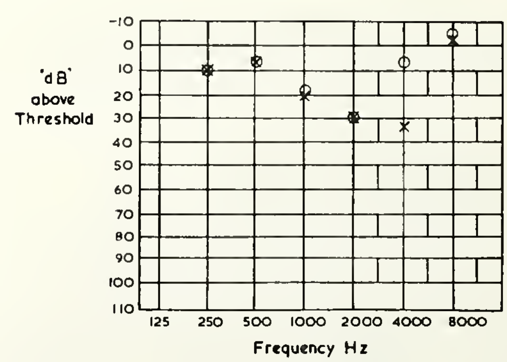

Figure 6. Results of an Audiometer Test on Operator No. 2.

Left ear --- X

Right ear--- O

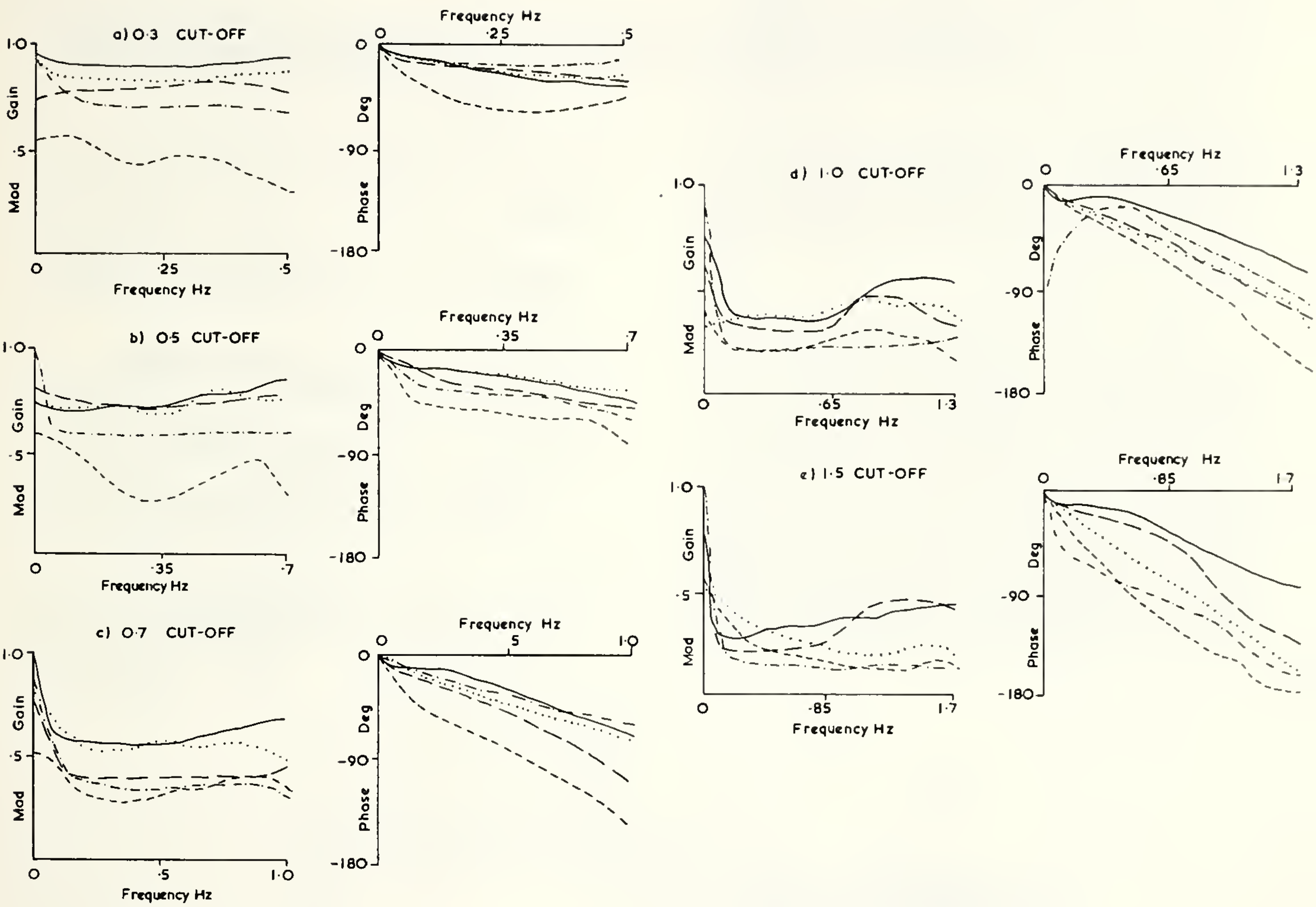

Figure 7. Measured Closed-Loop Frequency Response at Each Input Cutoff Frequency for Each Visual and Audio Error Signal Presentation.

Visual (V) ————————
Mark Space (A1) ---------

Matching Frequency (A2) .-.-.-.-.-
Doppler Matching (A3) ....
Amplitude Matching (A4) — — — —

fairer test on which to base conclusions on the acceptability of any particular form of auditory display would be conducted with trained operators. However, the authors believe that initial reactions are as true a guide as any. There is no quantitative way to allow for concentration lapses.

Figure 8 shows the range of results obtained for one particular test (beat-audio error-signal presentation with 0.7 Hz input cutoff frequency) for all five operators. The result for Operator 2 shows a resonant peak in the gain response at about 0.8 Hz while the phase shift at low frequencies tends to be: $\frac{\pi}{2}$ (unlike the other operators). This type of response occurs when the operator is over-reacting to changes in the input signal and subsequently overcorrecting. Again the variations in the responses measured would tend to advocate tailoring the audio display to the individual.

Human operator modeling. The model used (equation 7) has the advantage that the parameters can be given a physical interpretation. The Powell hill-climbing technique used to minimize a cost function between measured and modeled response values found the global minimum in the cost function over the parameter N-vector space and within the boundary values chosen. The choice of boundary values for the parameters was based on previous values used and on experience taking into account the physical limitations imposed by the human operator. The error function minimized was of the integral error squared form given by:

$$\mathrm{COST} = \frac{\int_0^{F_{MAX}} (H_{MEAS}(j\omega) - H_{MOD}(j\omega))^2 d\omega}{\int_0^{F_{MAX}} (H_{MEAS}(j\omega))^2 d\omega} + \frac{\int_0^{F_{MAX}} (G_{MEAS}(j\omega) - G_{MOD}(j\omega))^2 d\omega}{\int_0^{F_{MAX}} (G_{MEAS}(j\omega))^2 d\omega} \qquad (11)$$

where:

$H_{MEAS}(j\omega)$: measured closed-loop response

$H_{MOD}(j\omega)$: model closed-loop response

$G_{MEAS}(j\omega)$: measured open-loop response

$G_{MOD}(j\omega)$: model open-loop response

and:

$$H_{MOD}(j\omega) = \frac{G_{MOD}(j\omega)}{1 + G_{MOD}(j\omega)} \qquad (12)$$

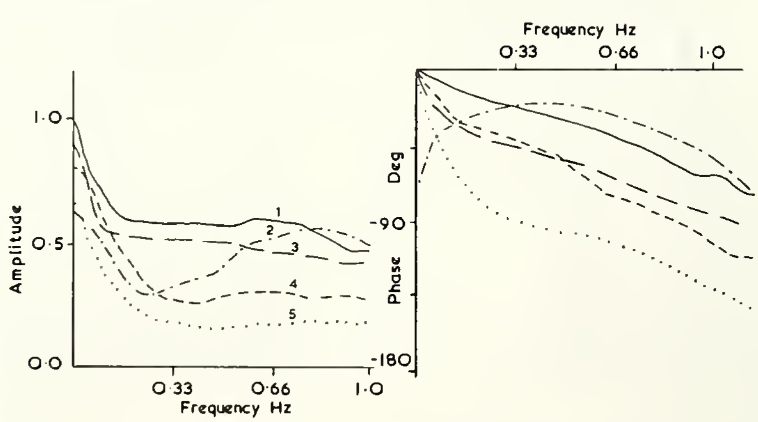

Figure 8. Results Obtained for the Doppler Matching-Audio Feedback with an Input Cutoff Frequency of 0.7 Hz.

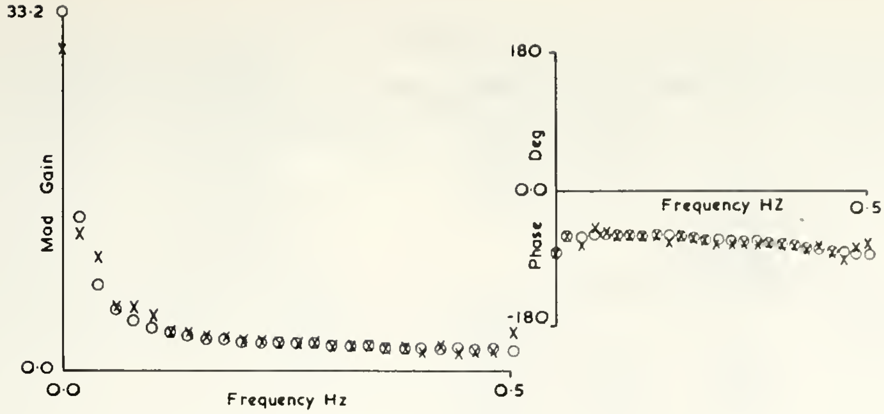

Figure 9. Measured and Modeled Frequency Response, Open-Loop, for a Human Operator Subjected to Tracking a Band-Limited White-Noise Input with 0.3-Hz Cutoff. (The Error Was Presented Visually.)

This cost function and hill-climb process thus optimizes the model parameters in terms of both open-loop and closed-loop measurements simultaneously. Figures 9 and 10 show typical results obtained from this modeling process for a visual test.

Table 1 lists the parameter values obtained from modeling the tests conducted on a single operator. A complete table for all five operators is not included for reasons of space. However, several points can be inferred from the results presented which are borne out in the results obtained for the other operators.

The human-operator gain (K) is a function of the sensitivity of the joystick and of the particular test environment chosen. However, as the input cutoff frequency increases, the gain decreases. This is borne out by Table 1 for all the various forms of error-signal presentation. It is also noticeable that the mark-space presentation (A1) displays the lowest overall gain figures which is compatible with predictions made from the coherency results. The beat-frequency presentation (A4) comes closest to the figures presented for the visual presentation; this again might be expected from the coherency results.

The lead factor (T_D) is a measure of the velocity control exerted by the operator; the larger the value of T_D the greater the velocity control exerted (the more sensitive the response to rate of change in the error function).

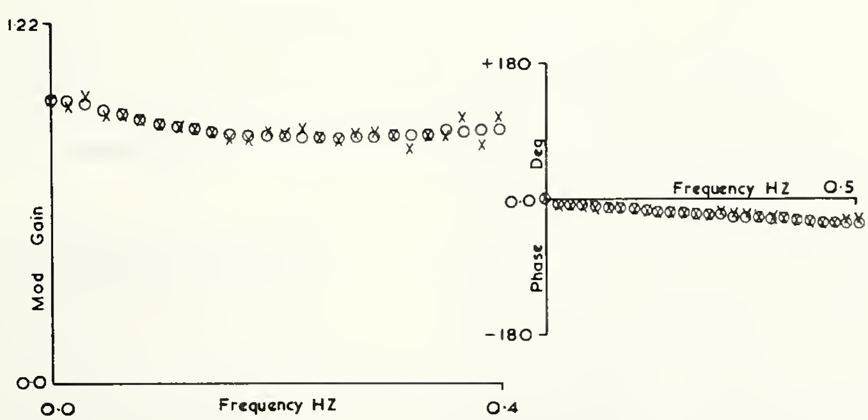

Figure 10. Measured and Modeled Frequency Response, Closed-Loop, for Human Operator Subjected to Tracking a Band-Limited White-Noise Input with 0.3-Hz Cutoff. (The Error Was Presented Visually.)

TABLE 1

Operator Model Parameter Values Plus Error Performance Figures for Single Operator

TEST Type of Display	Input cutoff frequency Hz	K	τ	C	T_D	T_S	COST	G_{FACT}	P_{FACT}
Visual	0.3	2.1	0.40	0.15	2.59	0.0	0.021	0.08	10.6
	0.5	0.94	0.33	0.17	2.26	0.0	0.02	0.20	18.0
	0.7	0.78	0.21	0.22	1.96	0.0	0.02	0.30	24.0
	1.0	0.43	0.18	0.33	1.77	0.0	0.013	0.46	33.7
	1.5	0.40	0.10	0.57	1.45	0.02	0.025	0.57	42.0
Mark space	0.3	0.41	0.3	0.10	1.30	0.004	0.02	0.54	38.0
	0.5	0.27	0.24	0.16	1.41	0.08	0.017	0.69	45.4
	0.7	0.27	0.23	0.16	0.87	0.06	0.04	0.72	72.2
	1.0	0.26	0.23	0.4	0.72	0.10	0.023	0.77	92.2
	1.5	0.33	0.18	0.70	0.35	0.09	0.07	0.86	108.7
Matching Freq.	0.3	1.02	0.27	0.11	1.17	0.001	0.013	0.32	23.1
	0.5	0.79	0.17	0.25	1.24	0.11	0.015	0.40	25.5
	0.7	0.36	0.16	0.20	1.31	0.07	0.009	0.61	46.5
	1.0	0.19	0.20	0.0	1.33	0.0	0.024	0.75	63.6
	1.5	0.21	0.19	0.08	0.67	0.004	0.035	0.83	87.8
Beat	0.3	1.52	0.40	0.0	1.46	0.003	0.024	0.14	18.1
	0.5	1.42	0.21	0.32	1.01	0.16	0.016	0.22	28.7
	0.7	0.97	0.12	0.25	1.02	0.20	0.02	0.37	48.4
	1.0	0.53	0.12	0.60	1.09	0.16	0.017	0.58	59.8
	1.5	0.28	0.15	0.13	1.05	0.154	0.02	0.75	100.6
Amplitude	0.3	1.22	0.39	0.26	1.16	0.002	0.022	0.25	23.0
	0.5	1.25	0.15	0.49	0.99	0.2	0.009	0.33	29.0
	0.7	0.59	0.13	0.64	1.15	0.189	0.02	0.55	48.5
	1.0	0.28	0.23	0.48	1.2	0.0	0.06	0.67	60.0
	1.5	0.10	0.18	0.25	1.9	0.05	0.04	0.81	80.2

The operator appears to maintain an approximately constant level of velocity control until at high frequencies he no longer responds to velocity, but degenerates into a form of bang-bang control. Under this last mode of operation it is purely the sign of the error that decides the controlling action. For some audio tests, notably the Mark Space Test, this degeneration into a form of bang-bang control occurs at input cutoff frequencies as low as 1 Hz and possibly even lower.

The operator's time delay (τ) decreases as the input cutoff frequency increases, Fig. 11. This result is well known. However, a slight increase in time delay was found at the high frequencies for the audio tests. This might be explained by the fact that at high frequencies signal interpretation becomes more complicated for the audio tests. This suggestion is only tentative and further tests are required.

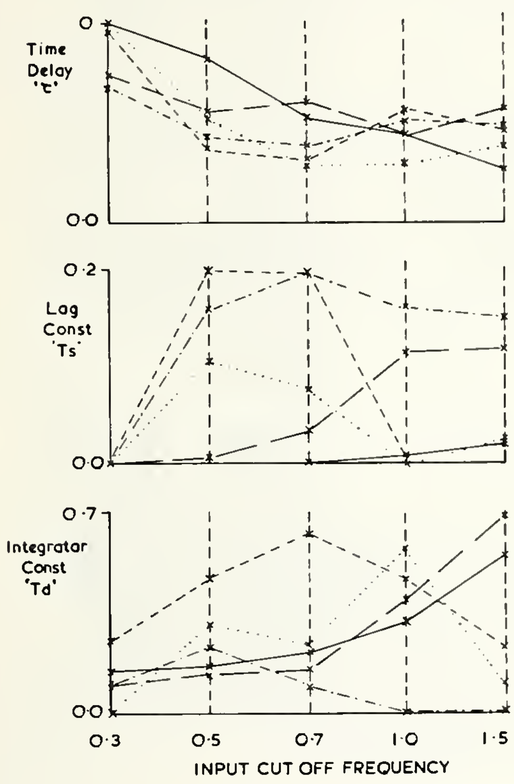

Figure 11. Variation of Three Model Parameters with Change in Input Cutoff Frequency for Each Form of Error Signal Presentation and for a Single Operator.

Visual	———————
Mark Space	——— ———
Matching Frequency	-.-.-.-.-.-.
Doppler	....
Amplitude Matching	-----------

The lag constant (T_s) is perhaps the most difficult to explain in physical terms. Due to the operator's time-delay response, the closed-loop response has a tendency to exhibit resonances at frequencies where the phase shift in the output leads to positive feedback. Thus, the operator can find himself correcting high-frequency components in the error signal which are not in fact present in the original input. All the operators tended to counteract this by ignoring, to a greater or lesser extent, high-frequency changes in the error signal. The model, as given by Equation 7, allows for this in the form of a low-pass element with a time constant T_s. The greater T_s, the lower the break frequency for the low-pass element. All the tests display low values of T_s for the 0.3-Hz cutoff with T_s increasing for the 0.5-Hz and 0.7-Hz cutoff frequencies. Beyond 0.7 Hz it depends on the test as to the degree of damping used. There appears to be a mode of operation for some of the audio tests in which the closed-loop resonance effect goes unnoticed and hence uncontrolled. This may be a function of the information being lost in the audio feedback at high frequencies. This is certainly true of the amplitude-matching and beat-frequency presentations.

Lastly the integrator factor (c) attempts to measure the ability of the operator to track low-frequency trends in the mean level of the signal. Surprisingly the Mark Space Tests show up quite well in this respect, being similar to the visual response at low frequencies. However, the variations in this constant are more a function of the operator's long term concentration and hence little can be said.

It must be emphasized that the discussion of changes in the model parameters is only applicable to these particular tests. Firmer conclusions require much more intensive testing. However, the trends listed

were consistently reproduced in tests conducted for a second time on a single operator, and lend weight to the applicability of the model. The model-cost function values listed in Table 1 give further reason for believing the model to be creditable.

Display performance estimates. Although a detailed study of the measured operator responses for various types of error presentation is instructive, it is too cumbersome a method for classifying particular forms of display. There are two ways of classifying an operator's response for a given input in terms of modulus gain response and phase response. Equation 8 defines a factor G_{FACT} which gives a measure of the mean-square deviation from unity gain over the frequency range of interest, while Equation 9 describes a similar factor (P_{FACT}) assessing the deviation of the phase response from a desired zero-phase shift. These factors are listed in Table 1 for each test. The weight placed on G_{FACT} as opposed to P_{FACT} depends on the type of task to be performed.

Ideal values are:

$$G_{FACT} = 0.0$$

$$P_{FACT} = 0.0$$

It can be seen in Table 1 that the visual display scores best on both counts. The Beat Frequency Test has an edge on the Amplitude Matching Test, followed by the Frequency Matching Test. The Mark Space Test scores lowest. This ordering agrees substantially with other results presented and confirms that G_{FACT} and P_{FACT} would appear to give a reliable performance index.

CONCLUSIONS

Experiments showed that human operator performance depends on the frequency content of the input. It would appear that for visual-tracking tasks the operator can adapt his response to suit the input. However, it was found that his adaptability, and hence performance, was impaired by audio presentation of the signal. Contrary to comments made by Vinje and Pitkin (1971), the human operator response to the audio cues presented in these experiments was consistently inferior to visual cues. However, audio presentations used here were different from those used by the above authors.

The linear model used to describe the operator's response fitted the measured response well for low-frequency input tests. However, when the input signal contained high-frequency components, operator response might be better described by the incorporation of a non-linear bang-bang control element in the model. For this reason the physical interpretation of the model parameters is still open to argument. The description presented here is subjectively consistent with the experience of the subjects tested.

The presentation of a gain-and-phase cost function to measure the "goodness" of operator response has the advantage of retaining information about phase response in its crudest form while retaining overall information on the modulus of the response. A simple presentation of error variance to input variance gives no useful information about the nature of the response.

Finally, this article serves as an introduction to a more thorough analysis of two- and three-dimensional audio displays as an alternative, or in conjunction with visual displays. Extension to two-dimensional displays introduces cross-coupling effects which, although not too serious for visual tracking tasks, could prove detrimental to performance for certain combinations of audio displays.

Black, W. L. An acoustic pattern presentation. *Research Bulletin 16.* New York: American Foundation for the Blind, May 1968, 93-132.

Blackman, R. B. & Tukey, J. W. *The measurement of power spectra.* Dover Publications, 1958.

Fish, R. M. & Beschle, R. G. An auditory display capable of presenting two dimensional shapes to the blind. *Research Bulletin 26.* New York: American Foundation for the Blind, June 1973, 5-18.

Fletcher, R. & Powell, M. J. D. A rapidly convergent descent method for minimisation. *British Computer Journal*, 1963, 6, 163-68.

Gill, J. M. Auditory and tactual displays for sensory aids for the visually impaired. *Research Bulletin 29.* New York: American Foundation for the Blind, 1975.

Kramer, H. J. Stimulus variables in auditory projective testing. *Research Bulletin 1.* New York: American Foundation for the Blind, January 1962, 33-40.

Krendel, E. S., McRuer, D. T., & Graham D. The analysis and synthesis of manual closed loop control systems. *1966 IEEE International Convention Rec.*, 193-95.

Mudd, S. A. Experimental evaluation of binary pure-tone auditory displays. *Journal of Applied Psychology*, 1965, 49(2), 112-21.

Phillips, J. A. & Seligman, P. M. Two instruments for the blind engineer. *Research Bulletin 27*, New York: American Foundation for the Blind, April 1974, 187-216.

Pollack, I. & Ficks, L. Information of elementary multi-dimensional auditory displays. *Journal of the Acoustical Society of America*, 1954, 26(2), 155-58.

Roffler, S. K. & Butler, R. A. Factors that influence the localization of sound in the vertical plane. *Journal of the Acoustical Society of America*, 1968(a), 43(6), 1255-9.

Roffler, S. K. & Butler, R. A. Localization of tonal stimuli in the vertical plane. *Journal of the Acoustical Society of America*, 1968(b), 43(6), 1260-6.

Vinje, E. W. & Pitkin, E. T. Human operator dynamics for aural compensatory tracking. *7th Annual Conference on Manual Control*, NASA SP-281, June 1971, 339-48.

Wellstead, P. E. Aspects of real time spectral analysis. Ph.D. Thesis, University of Warwick, England, 1971.

Young, L. P. On adaptive manual control. *IEEE MMS-10*, December 1969, 292-331.

A PILOT STUDY ON THE DISCRIMINABILITY OF TACTILE AREAL AND LINE SYMBOLS FOR THE BLIND

G. A. James* and J. M. Gill**

Abstract: Eight tactile areal and 17 linear symbols for use on maps and graphics for the blind were produced on Brailon and tested for discriminability in separate sets by the method of paired comparisons. Subjects' response times were recorded as latencies. The results indicated that only 5 of the areal symbols but 10 of the linear symbols met the stringent criteria for discriminability suggested by Nolan and Morris (1971). Errors in discrimination are discussed with reference to the parameters which contribute to the discriminability of the symbols used in the study, and latencies are discussed in relation to "response set."

INTRODUCTION

It has been shown that there is a need for tactile maps and diagrams for blind schoolchildren. Leonard and Newman (1967 and 1970) demonstrated that at least half of the subjects in a study were able to complete an unfamiliar route with the aid of a tactile map to provide the relevant information.

Tactile maps and diagrams are composed of three categories of symbols: line symbols to designate boundaries or lines, areal or texture symbols for areas, and point symbols to show specific locations or landmarks. This study is concerned only with areal and line symbols.

Several studies have attempted to define sets of discriminable tactile areal and line symbols for the blind. Heath (1958) conducted a pioneer study by examining the discriminability of 40 tactile areal symbols using the method of constant stimulus differences to compare symbols randomly grouped in sets of 10. He also found that areal symbols remained legible at a size of 50 x 50 mm. Culbert and Stellwagen (1963) also examined the discriminability of textural surfaces and found 11 out of 40 different patterns discriminable enough from all the others to be useful in the preparation of material such as maps for the blind. Nolan and Morris (1971) conducted several studies which represent the most extensive source of information. Their findings show that the number of tactile areal or line symbols which are discriminable in a set may not exceed 8 or ten. They relate this perceptual limit to the parameters which distinguish tactile symbols. A flexible production system is therefore an essential requirement in varying these parameters as much as possible in an attempt to increase the number of legible tactile symbols within a set.

PRODUCTION METHOD

The study conducted by Heath (1958) used the Virkotype or Gestetner printing method. Wet ink print was

*Blind Mobility Research Unit, University of Nottingham, England.

**Inter-University Institute of Engineering Control, University of Warwick, England.

dusted with a fine resinous powder which adhered to the wet ink and appeared as a raised plastic symbol when heated. The disadvantages of this method were stated by Nolan and Morris (1971): the degree of relief is poor (0.11 mm.), control of quality is poor, and the medium deteriorates in humid conditions.

The production method used in the Nolan and Morris studies involved reproducing the symbols to be studied by photoengraving in zinc. The master was then pressed into soft plaster which was then allowed to harden. The moulds were then used as masters to produce vacuum-formed copies in plastic 0.20 mm. thick. Embossed symbols were produced at a relief varying from 0.46 mm. to 0.62 mm.

In this country a variety of production methods have been investigated by Pickles (1970). Briefly, this type of approach involves building up a master map or diagram on transparent cellulose. Various thicknesses of string and wire are used for line symbols; sandpapers, linoleum, and fabrics are used for textures. The master can then be used to produce copies in Brailon on a Thermoform machine.

The production methods briefly described are generally time-consuming and therefore expensive if the cost of labor is taken into account. Recent developments at the University of Warwick are based on computer-aided design principles. The relief and type of line or texture is input to a computer from a keyboard. Symbol parameters can be varied accurately to include various heights of solid, dotted, dashed, and dot-dashed lines. Symbol specifications are stored by the computer. Once the symbols have been specified the master is engraved in a sheet of Tufnol by a computer-controlled machine tool. A positive copy of the engraved master is made using silicone rubber. Copies are produced in 0.18 mm. Brailon on a Thermoform machine.

This study is an initial attempt to define some of the parameters governing the discriminability of areal and line symbols produced by a computer-controlled method.

METHOD

Subjects

Sixty-two blind schoolboys were used as subjects. The age range was from 11 years 3 months to 19 years 1 month. This sample represented all braille readers who were available and in full-time education at Worcester College for the Blind. I.Q. scores, chronological ages, and braille reading speeds were obtained from the school. They assessed braille-reading speed in the following way:

1. Boys read braille out loud to the whole class for 3 minutes.

2. A score was taken for the number of braille-lines completed.

3. The number of lines completed was then multiplied by 3/4 to give an average speed in pages of braille per hour.

Apparatus and Selection of Symbols

Figures 1 and 2 show the apparatus. A wooden board with a frame was used to hold the stimulus cards. Some previous studies have used a blindfold to exclude residual vision of some blind subjects but this may introduce psychological stress.

Figure 1. Experimental Apparatus.

Figure 2. Experimental Apparatus.

Therefore, a screen with a curtained opening for the subjects' arms was used. The stimulus cards were contained in a filing tray. A stopwatch was used to record response times.

Selection of tactile symbols for testing was guided by previous research. Areal symbols were varied along the dimensions of continuous and interrupted, density of the pattern size of the figures making up the pattern, and the use of vertical, horizontal, and diagonal lines to differentiate patterns. Linear symbols were continuous and interrupted, thick and thin, single and double, and smooth edge and broken edge. The interrupted lines were varied with more than one spacing.

Areal and linear symbols were produced in Brailon. The areal ones were 50 x 50 mm. in size and the linear ones were 100 mm. in length. Areal and linear symbols were tested in separate sets. Figures 3 and 4 show how the former were mounted side by side and the latter one above the other on stiff card 120 x 100 mm. The left/right, or up/down position of the symbols was determined randomly. The relief of the tactile symbols was 0.7 mm.

DESIGN

Symbols within each separate set were compared by means of paired-comparison: each symbol in a set was compared with itself and every other.

Figure 3. Position of Subject's Hands for Examination of Areal Symbols.

The 8 areal symbols gave 36 combinations, and the 17 line symbols gave 153 combinations. Three sample pairs of symbols were used to familiarize the subject with the procedure.

The order of presentation of the paired symbols was determined randomly.

PROCEDURE

Two examiners tested the subjects using the following Standard

Figure 4. Position of Subject's Hands for Examination of Linear Symbols.

Instructions:

Textures

Please put both of your hands through the curtain onto the raised symbols in front of you. You will find two symbols side by side.

Are these symbols the same or different? (E gives knowledge of results.)

There is no time limit, but remember that once you have made a decision you cannot change your mind. Give the answer "same" or "different."

There will be two more test symbols to be sure you understand. I will tell you if you are right or wrong, but this time do not touch the symbols until I say "Now."

Are there any questions? (Questions are dealt with by repeating the relevant parts of the instructions.)

We will now begin the experiment. I am *not* able to tell you if you are right or wrong from now on. Remember not to touch the symbols until I say "Now."

Lines

This time the two symbols are lines, and they are one above the other. Concentrate on the center of the lines and not the ends. First there will be three test symbols to be sure you know what to do. (E gives knowledge of results.)

Are there any questions?

We will now begin the experiment. I am *not* able to tell you if you are right or wrong from now on. Remember not to touch the symbols until I say "Now."

This experiment is much longer than the first one, so there will be two short breaks of one minute each.

Each subject examined every pair of symbols and had to report whether they were the "same" or "different." The examiner recorded the time to the nearest second from when the subject touched the stimulus card to when he made the decision. To prevent knowledge of results only one stroke of the pen was made by the examiner in a "right" or "wrong" column on the scoring sheet.

Total time taken to complete the test was about 40 minutes. This included three 60-second rest periods.

CRITERIA

Jenkins (1947) used the method of paired comparisons to define a discriminable set of tactile aircraft control levers. He excluded any shapes confused by more than one percent of the subjects. The effects of making an incorrect decision with aircraft controls are evident and justify the extremely stringent criteria.

Nolan and Morris (1971) report the following criteria as being the most useful in selecting discriminable tactile symbols for the blind:

1. Average confusion with other acceptable symbols must be five percent or less.

2. Confusion with itself or any other single symbol acceptable by criterion 1. should be 10 percent or less.

3. Any symbols acceptable by criterion 1. and 2. must be independent of academic grade differences.

Nolan and Morris' criteria are not supported by any rationale, but as quite stringent arbitrary criteria 1. and 2. were adopted for the purpose of this study. Criterion 3. was not adopted because it was considered that IQ, chronological age, and braille reading speed were more reliable variables than "grades."

RESULTS

For the purpose of analysis, braille reading-speed scores were classed into frequencies as shown in Fig. 5. On the basis of these data the experimental group was divided into low- medium- and high-speed braille readers. Subgroups were comprised of 16, 26, and 20 subjects respectively. Tables 1 and 2 show

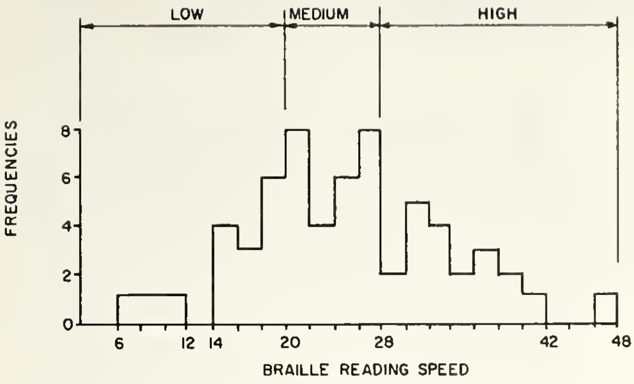

Figure 5. Braille Reading-Speed Frequencies.

that the mean error was no more than 2 on the areal symbols and no more than 5 on the linear ones.

TABLE 1

Correct Responses Within Braille Reading-Speed Groups for 36 Combinations of 8 Areal Symbols

	Low	Medium	High	Total
Mean	35.12	34.53	34.75	34.80
Range	31-36	28-36	31-36	28-36
N.	16	26	20	62

TABLE 2

Correct Responses Within Braille Reading-Speed Groups for 153 Combinations of 17 Line Symbols

	Low	Medium	High	Total
Mean	148.25	148.07	149.70	148.86
Range	141-152	131-153	143-153	131-153
N.	16	26	20	62

Krushal-Wallis one-way analyses of variance for braille reading-speed groups and performance were computed separately for areal and linear symbols. For areal symbols, H was 1.00 and for linear symbols, H was 2.03, values too low to be significant at the 0.05 level.

No correlations were found between chronological age and performance or IQ and performance for areal or linear symbols.

Tables 3 and 4 show the percentage of errors for areal and linear symbols. (Areal symbols are indicated by upper case letters and linear symbols by lower case.) After excluding B, D, and H the remaining areal symbols were A, C, E, F, and G; these indicated by an asterisk in Fig. 6.

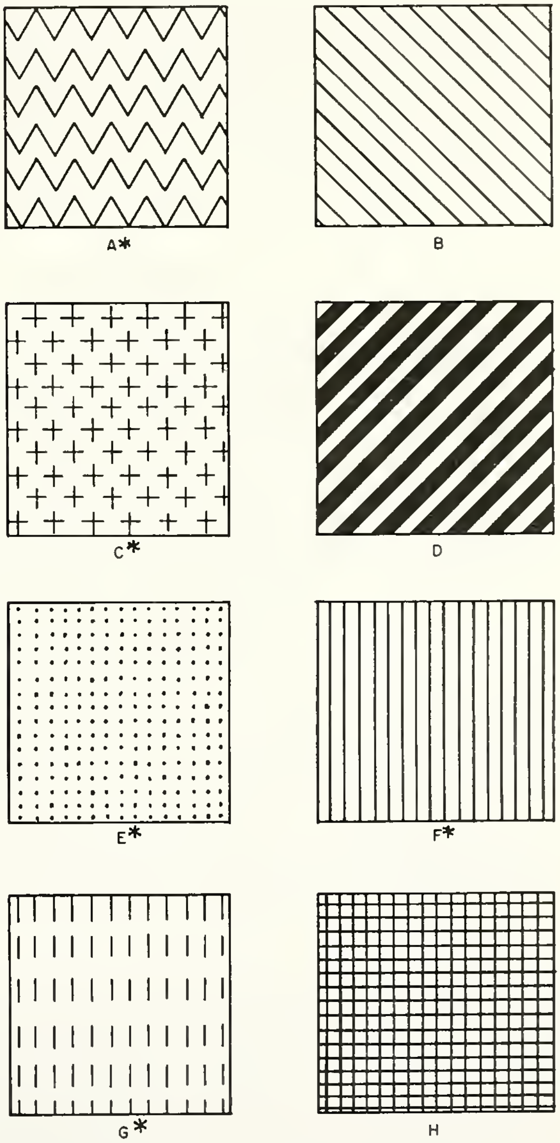

Figure 6. Outside Dimensions of Eight Plastic Areal Symbols, 50 mm. Square. Asterisks Identify a Discriminable Set.

TABLE 3

Percentage of Errors on Areal Symbols

	A	B	C	D	E	F	G	H
A	4.8	1.6	3.2	1.6	0	1.6	4.8	0
B		11.2	1.6	20.9	0	3.2	0	0
C			9.6	1.6	3.2	0	1.6	0
D				14.5	0	1.6	0	0
E					1.6	1.6	3.2	1.6
F						0	4.8	3.2
G							8.0	0
H								11.2

TABLE 4

Percentage of Errors in Line Symbols

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q
a	1.6	4.8	0	0	0	0	1.6	0	1.6	6.4	0	0	0	1.6	0	0	0
b		3.2	0	0	0	0	3.2	0	1.6	3.2	0	0	0	0	0	0	0
c			6.4	6.4	1.6	0	0	0	0	0	0	0	0	0	0	0	0
d				3.2	0	0	1.6	1.6	0	0	0	0	0	1.6	0	0	0
e					8.0	62.9	3.2	17.7	0	0	0	0	1.6	6.4	0	0	1.0
f						6.4	1.6	11.2	1.6	1.6	0	0	3.2	4.8	0	1.6	3.2
g							4.8	1.6	0	3.2	0	0	0	0	0	0	0
h								20.9	1.6	0	0	0	1.6	4.8	0	0	0
i									3.2	33.8	0	3.2	0	1.6	0	1.6	0
j										3.2	0	0	0	0	1.6	0	0
k											11.2	0	0	0	0	0	14.5
l												4.8	0	0	4.8	30.6	1.6
m													17.7	9.6	0	0	0
n														12.9	0	0	0
o															0	17.7	0
p																4.8	0
q																	8.0

After excluding m, h, k, n, p, j, and e the remaining linear symbols were a, b, c, d, f, g, i, l, o, and q; these indicated by an asterisk in Fig. 7.

Mean latencies for areal and linear symbols are shown in Tables 5 and 6 respectively. Latency differences between like and different pairs of symbols were assessed for areal and linear symbols separately. The standard mean latency for different areal symbols was 2.94 and for like pairs was 5.78, and for linear symbols the corresponding figures were 2.45 and 5.23. To give the significance of the latency differences for like and different symbols the Mann-Whitney U-test was applied and it was found that the differences for both areal and linear symbols were significant at less than the 0.001 level.

DISCUSSION

The study was successful in increasing the number of discriminable tactile linear symbols from the 8 found by Nolan and Morris (1971) to 10. However, this does not exceed the upper limit of 10 suggested by Nolan and Morris, and adds further evidence to the theory that there may be an inherent limitation in the variety of tactual discriminations a person can make on symbols of this kind. Alternatively, there may be limitations in the experimental design and it is hoped in future research to investigate this problem. The distinguishing parameters for linear symbols are evident from Fig. 7. For interrupted lines, spacing is a distinguishing parameter for dotted lines (c, d) but not for dashed lines (e, f). Lines with edges broken by vertical projections (k, m and n) are easily confused and the use of projecting lines of differing angles might be useful.

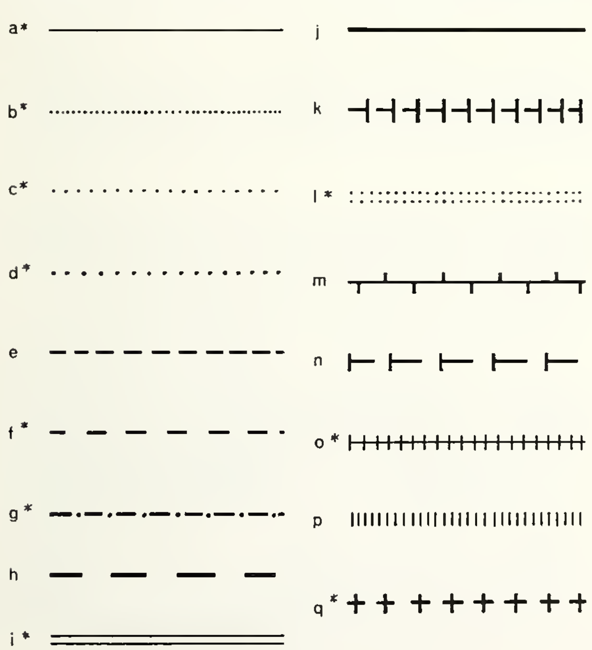

Figure 7. Seventeen Linear Plastic Symbols, 100 mm. Long. Asterisks Identify a Discriminable Set.

Areal symbols had a limited range, but we confirmed Nolan and Morris' finding that if the areal pattern is basically similar, as in B and D, change of direction on diagonals is not a good cue for discrimination. This is a cognitive problem and might be solved by introducing perceptual training.

One self-error in the areal symbols and four in the linear ones detracted from the number of legible areal and line symbols. Had it not been for these errors, six out of eight areal symbols would have been discriminable and 12 out of 17 lines. One explanation for self-errors is that subjects may be examining the symbols too closely for subtle differences which do not exist, alternatively subjects have a response set for saying "different" when in actual fact they mean "same."

Results for latencies oppose the "mental set" explanation for like-pair errors. Subjects spent significantly more time discriminating like-pairs of symbols as compared with different. Although one subject did remark "It becomes mechanical after a while," the evidence shows that subjects did not continue answering "different" when the symbols were the same.

A criticism of this study is that the symbols were presented in the same random order to each subject. In view of the length of the test (40 minutes) practice and fatigue could have been compensated for by alternating the order of presentation. A further criticism is that time-keeping by stopwatch was both tiring for the experimenters and inaccurate, and

TABLE 5

Mean Latencies for Areal Symbols (Seconds)

	A	B	C	D	E	F	G	H
A	5.89	3.22	3.45	3.09	2.32	2.48	3.08	2.22
B		6.42	2.87	6.14	2.11	2.84	3.08	1.87
C			9.13	3.05	3.08	2.00	3.30	2.88
D				6.44	2.11	2.47	2.72	2.72
E					3.26	2.90	4.19	2.56
F						4.40	3.29	3.45
G							5.42	2.98
H								5.32

TABLE 6

Mean Latencies for Line Symbols (Seconds)

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q
a	3.01	2.82	1.90	1.87	2.20	1.96	2.45	2.00	2.22	3.06	2.31	1.85	2.68	2.52	2.03	1.61	2.05
b		3.62	2.08	1.98	2.23	1.96	2.83	2.25	2.14	2.56	2.12	1.93	2.22	2.24	1.88	2.12	1.90
c			4.79	3.16	2.00	2.54	2.46	2.35	1.67	1.83	2.12	2.09	1.96	2.42	2.04	2.09	2.27
d				6.54	2.09	2.37	2.13	2.85	1.81	1.61	1.96	1.72	2.09	2.45	2.05	2.29	2.29
e					4.08	6.35	3.19	3.83	2.32	2.17	2.09	2.14	2.62	3.93	2.17	2.08	2.24
f						6.59	2.41	4.09	1.98	2.87	2.66	2.00	3.09	3.82	2.03	1.95	2.30
g							5.87	2.87	2.45	2.08	1.96	1.93	2.52	2.98	2.16	2.46	2.25
h								6.45	2.13	1.90	2.04	2.61	3.20	3.22	2.48	2.00	2.17
i									3.24	4.30	2.04	2.00	2.45	2.55	2.48	2.19	2.03
j										4.00	2.16	2.01	2.50	1.96	2.37	2.17	2.08
k											6.66	1.95	3.72	2.61	2.16	2.48	4.55
l												4.80	2.35	2.43	3.01	4.87	2.04
m													7.67	4.96	2.66	2.03	3.06
n														4.46	2.25	1.88	3.34
o															6.70	4.62	2.95
p																5.70	2.22
q																	4.79

more sophisticated timing would be useful in future work.

Future work on areal and linear symbols should include a more systematic analysis of the parameters which contribute to discriminability, and a consideration of the effect of variation in symbol relief to increase information redundancy.

Immediate research includes the assessment of discriminable tactile point symbols, including upper-case letters of the English alphabet, and an examination of the usefulness of this type of tactile code for school-children and adults who are braille and non-braille readers.

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REFERENCES

Culbert, S. S. & Stellwagen, W. T. Tactual discrimination of textures. *Perceptual and Motor Skills*, 1963, 16, 545-52.

Heath, W. R. *Maps and graphics for the blind: Some aspects of the discriminability of textural surfaces for use in areal differentiation.* Ph.D. thesis, University of Washington, 1958.

Jenkins, W. O. The tactual discrimination of shapes for coding aircraft-type controls. In Fitts, P. M. (Ed.): *Psychological research on equipment design.* Washington, D.C.: U.S. Govt. Printing Office, 1947.

Leonard, J. A. & Newman, R. C. Spatial orientation in the blind. *Nature*, 1967, 215, 1413-14.

Leonard, J. A. & Newman, R. C. Three types of "maps" for blind travel. *Ergonomics*, 1970, 13, 165-79.

Nolan, C. Y. & Morris, J. E. *Improvement of tactual symbols for blind children.* Final Report, American Printing House for the Blind, 1971.

Pickles, W. J. Raised diagrams pp. 118-45 in *The teaching of science and mathematics to the blind.* London: The Royal National Institute for the Blind, 1970.

Siegel, S. *Nonparametric statistics for the behavioural sciences.* New York: McGraw-Hill Book Co., 1956.

AN ANALYSIS OF OPTACON USAGE

Loren T. Schoof II*

Abstract: Three topics are explored which relate to Optacon usage. The first topic is the categorization of Optacon users according to occupation. Where relevant, the data presented here are compared with those of the earlier American Foundation for the Blind survey (Goldish and Taylor, 1974). A major change is that students have become the largest group of Optacon users, replacing computer professionals. However, a wide range of occupational categories is represented and a breakdown is given for those people trained at Telesensory Systems, Inc.

The second topic is a statistical analysis of factors which affect the performance levels attained by the end of the TSI training course. A total of 41 participants in this course during 1973 and 1974 form the data base for this analysis. Two variables were considered as measures of performance: Optacon reading speed and letter recognition. The latter proved to be unsuitable for statistical analysis. The factors which were analyzed for their effect on Optacon reading speed were age, sex, age of onset of blindness, and braille reading speed. An analysis of variance showed that the only factor which had a statistically significant effect was the age of the participant at the time of training. The results of this analysis have been updated with seventeen additional participants. It is also shown that, during the time period under investigation, there appears to be no significant change in the effectiveness of the training courses.

The third topic is a description of how people in different occupational groups are using the Optacon on the job. Although the results are qualitative, it does appear that those in entry-level positions are more strongly motivated to take advantage of the Optacon on the job. People past the entry-level position seem to find the Optacon enables them to plan and organize their work more efficiently. The ability to read confidential information without assistance of another person also appears to be of importance to Optacon users. All of the people interviewed felt that the Optacon was of significant value to them in their employment.

INTRODUCTION

Since the Optacon (a portable, direct translation, inkprint reading aid for the blind) first became available in 1971, a number of studies and surveys have been conducted on topics related to the process of learning to use it, as well as its application. Tobin, James, McVeigh, and Irving (1973), and Weisgerber, Everett, Rodabaugh, Shanner, and Crawford (1974) have attempted to identify predictors of performance in an Optacon training course. Goldish and Taylor (1974) have surveyed Optacon users to determine how important the Optacon has proven to be in daily life.

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*Sensory Aids Specialist, Telesensory Systems, Inc., Palo Alto, California 94304.

Editor's Note: Mr. Schoof, who is blind himself, performed all of the statistical analyses he describes in this paper with an Optacon, HP-35 Calculator, and a Perkins Braillewriter as his only aids.

The studies relating to Optacon learning have tended to follow the same pattern. The researcher develops a set of training methods and materials based upon his own theory of education and his assumed performance criteria. He then selects a group of subjects who have different levels of characteristics which he believes may affect Optacon learning. The subjects are briefly trained toward these performance criteria with the Optacon, according to the methods he has developed. At the end of training, measurements of variables which reflect achievement according to these performance criteria are obtained. An analysis is performed to ascertain which factors have a statistically significant effect on Optacon performance. The Optacon students are then dismissed without any assurance of access to an Optacon no matter what their performance in the training.

Telesensory Systems training methods have been developed through an iterative process. They are intended to help the student integrate the Optacon into his daily life as quickly as possible. At the end of training, a student knows that the Optacon will be his no matter what his performance during the course. Since the student will retain use of the Optacon after training, there would seem to be significantly more motivation for a student to learn to use the Optacon in this situation. However, the TSI training courses are individualized to each student's desires and needs. For example, if a student and the teaching staff decide it is more appropriate, in relation to the student's projected needs, to emphasize instruction on the format of certain documents rather than on speed building, the resulting course will reflect this emphasis. Thus, because these courses are designed to provide a service to the blind individual rather than fulfill a research purpose, the goals of the training vary according to each individual's needs.

Approximately one year ago, the American Foundation for the Blind conducted a survey of Optacon users (Goldish and Taylor, 1974). Among other topics covered was a breakdown of Optacon users by occupation. Since that survey, a number of Optacon dissemination programs have been undertaken. These programs have made it possible for people who would not otherwise be able to afford an Optacon to do so. These programs may have significantly changed the occupational distribution of Optacon users. Also, a number of questions have been raised about the suitability of the Optacon in some occupational situations. Based on brief studies of Optacon learning and on interviews with newly trained users, some researchers have made claims about the appropriateness of this device which would seem to be no more than conjecture (Tobin, et al., 1973).

In view of the problems cited above with previous Optacon-related research, it seemed appropriate that another paper be prepared which would take into account some of these problems. The survey of occupations of Optacon users has been updated to reflect the rapid increase in the number of Optacon users. A statistical analysis of Optacon learning of TSI trained students has been made. However, the variables in this type of analysis do not necessarily reflect the utility of the Optacon to a blind person. To overcome this problem, a series of in-depth interviews are presented which give a greater feeling for how people in different occupations are using the Optacon.

PART I—OCCUPATIONS OF OPTACON USERS

Before coming to TSI for training, each Optacon student fills out a personal information form. One of the questions concerns the student's occupation at the time he receives Optacon training. From this and other sources, the occupations of 250 Optacon users were determined. Table 1 summarizes this information in terms of percentage of the sample for each occupational group together with the corresponding information from Goldish and Taylor, 1974.

While this is by no means an exhaustive sample of all Optacon users, it does give some idea of the occupational groups which are taking fullest advantage of the Optacon. Since the AFB survey, there are two changes worth noting: 1) students have replaced computer professionals as the largest single group using the Optacon, and 2) housewives have now

TABLE 1

Occupations of Optacon Users (General)

Occupation	TSI Sample (Percent)	AFB Survey (Percent)
Student	25.90	20
Computer Professional	22.31	23
Social Worker (Counselor or Administrator)	17.13	14
Housewife	12.79	8
Business (Clerical and Administrative)	11.55	13
College Professor or Administrator	3.98	4
Teacher (Elementary and Secondary)	2.39	--
Attorney	3.59	3
Engineer and Scientist	1.99	5
Other	0.80	8

replaced business and clerical workers as the fourth largest occupational group using the Optacon. The increase in the number of students using the Optacon can probably be explained by the growing interest of school systems in providing Optacons and Optacon training, and by the program of the Richard King Mellon Foundation. This program has allowed many people such as students and housewives to obtain what would otherwise be a prohibitively expensive piece of equipment.

Within each of these broad occupational categories, there is a wide diversity of possible job definitions. For the sample of 250 Optacon users, a more detailed breakdown of occupations was not possible. However, for those students trained at TSI, Table 2 gives a more specific breakdown of their occupations. In addition to those listed in the table, a television producer, a braille proofreader, and a meteorologist with the National Weather Service have become Optacon users.

TABLE 2

Occupations of Optacon Users (Detailed)

Students	
Elementary (6-13 years)	5
High School (14-17 years)	1
College (18-21 years)	21
Graduate School	11
Housewives	3
Business	
Receptionist	2
Dictaphone typist	3
Secretary	2
Technician	2
Assembler	1
Systems Analyst	3
Programmer	43
Information person	1
Expediter	1
X-ray film processor	1
Finance	1
Personnel	1
Taxpayer Service Rep.	1
Field Rep. for Company	1
Professional	
Engineering	4
Physicist	1
Attorney	4
Teacher (Elem. & High School)	5
Librarian	1

TABLE 2 (Contd.)

Professional (Contd.)

Psychologist	2
Sociologist	1
School Coordinator	1
College Professor	5
College Dean	2
High School Counselor	1
Counselor	3
Rehab. Director/Center	1
Rehab. Administrator	5
Rehab. Teacher	8
Rehab Counselor	8
Newscaster	1
Minister	1
Foreign Veteran	1
Coffee Shop Owner	1

PART II—STATISTICAL ANALYSIS OF TSI TRAINING COURSE DATA

The data used in this analysis was gathered from July 1973 through February 1974. The people who come to TSI for Optacon training are not considered to be subjects in an experiment. They have paid a fee to attend the course and have, either through purchase or other means, guaranteed access to an Optacon at the end of training. The objective of Optacon training is to enable them to use the Optacon on the job and in other daily activities.

Optacon trainees were asked to take tests which would measure the variables used in this analysis. They were not required to do so and, in fact, a number of individuals refused. Out of the total number of people trained during this time period, 41 data points were obtained. After the majority of the analysis had been completed, an additional 17 data points from the March, April, and May classes of 1974 were used to further update the resulting model. The actual number of students trained in that period was somewhat larger.

As with any statistical analysis, the results here apply only to the data upon which they are based. Any extension of them to other individuals must be based on the assumption that these results are true in general as well as for the sample analyzed. Furthermore, these are results at the end of a nine-day training course. They give no indication of what happened to Optacon reading performance after additional practice. To date, no quantitative follow-up studies have been done.

Training Procedures

Optacon training at TSI is an intensive course oriented to the needs of blind adults. Fifty to sixty hours of instruction are spread over nine class days. A one-to-one student/teacher ratio is maintained at all times. Teacher assignments are so arranged that the student works with a different teacher each day. A logging procedure has been developed so that each new teacher is familiar with the student's prior progress. The course work centers on five principal areas: equipment operation, letter recognition, tracking, speed building, and the format of common materials. These are not taught as separate topics, but must frequently overlap with one another. Letter recognition, for example, involves some practice in tracking.

The first area covered is the operation of the Optacon. The student learns the location and function of each of its controls. He learns how to adjust these controls to produce the best possible image on the tactile screen for the materials to be read. The teacher usually helps the student with the adjustments during the first few lessons.

Almost from the beginning, the student learns to recognize letter shapes and to synthesize them into words, phrases, and sentences. The materials used to introduce the student to print letters are in a simple, sans serif type font. Care has been taken to insure that this initial printing is as clear as possible. These measures allow the student to concentrate on the primary task of letter recognition. Later, as he becomes more skillful, other type styles and poorer quality print can be introduced. Upper case letters are introduced first since they seem to be more easily learned. The format of the lessons, however, is the same for both upper and lower case letters.

In general, a test is given at the beginning of a lesson to make certain that the student can identify letters that have previously been learned. If he is successful with this, a few new letters are introduced. A maximum of eight new upper case or five new lower case letters appear in a single lesson. After the student is satisfied that he can identify the new letters, another test is given. At the discretion of the teacher, the student can move to the next lesson or work with optional practice material included in the lesson. After a few letters have been learned, lessons are included which combine these letters into short words and sentences. As new letters are mastered, they are used in these practice lessons along with those letters previously learned.

Tracking, the skill of moving the camera across printed material, is developed concurrently with the letter recognition and speed building aspects of Optacon training. The first lesson a student encounters is designed to show him the stimulation from the tactile screen and the effect that camera movement has on that stimulation. At the start of training, the student uses a tracking aid to make this task somewhat easier. This device allows him free movement of the camera in the horizontal direction while restricting its vertical motion. As the student's ability to relate camera motion to the image on the tactile screen improves, the restriction on the vertical motion of the camera is relaxed. Finally, the student moves the camera freely without the use of a tracking aid.

The latter stages of the training course are devoted to helping the student integrate the Optacon more rapidly into his daily activities. This help is in two main areas: increasing the student's reading speed and familiarizing him with the format of materials he will frequently be using. In the first of these areas, a number of short stories have been included in the materials used at TSI. These stories allow the student to practice both his reading and tracking skills.

A piece of equipment, the Automatic Page Scanner, is also used in training. It moves the Optacon camera across a page of printed material at a fixed rate of speed. This relieves the student of the tracking task. He is forced to spend less time on recognizing individual letters. Instead, he must try to read whole words and to use context to anticipate new material.

The student can make more effective use of the Optacon if he can take advantage of the special formats of some printed materials. Samples of formats such as dictionary pages, bank statements, computer listings, and memos are included in the training materials. The teacher can show the student how to take advantage of the format to quickly find important information. Students who come to TSI for training are also encouraged to bring samples of the materials they are interested in reading.

A more detailed description of Optacon training at TSI can be found in the *Teaching Guidelines* manual listed in the bibliography. Methods described here are the result of experimentation and revision over a period of several years. Some of the papers listed in the bibliography show how the direction and emphasis in Optacon teaching have changed over the years (Weihl, 1971; Baer and Hill, 1972). No lesson plan or teaching technique has been preordained as the one absolutely correct method. Indeed, the procedures outlined above will continue to be revised as additional experience is acquired.

Choice of Variables for Analysis

The only truly valid measure of Optacon learning is the extent to which an individual trained in its use becomes dependent on it. This is, however, difficult to measure in a quantitative manner. The variable most commonly used as a measure of performance in training has been Optacon reading speed. This variable was used in the English Optacon evaluation (Tobin, et al., 1973) and in the Office of Education evaluation (Weisgerber, et al., 1974). Weisgerber also used a letter recognition test as a measure of reading accuracy. Both of these variables were measured for use in this analysis.

Since this was not an experimental program, it would have been

difficult to insist that Optacon students undergo a battery of physical and psychological tests. The variables selected for their possible effect on Optacon learning performance had, therefore, to be measurable without undue imposition on the students. Braille reading speed, for example, seemed to be a reasonable, if crude, measure of tactile sensitivity. Tobin, et al. (1973) found that this variable was significantly correlated with Optacon reading speed. Weisgerber, et al. (1974), however, found that there was no relationship between braille reading speed and Optacon reading speed. They did report a relation between this variable and Optacon reading accuracy. Tobin also found a significant relationship between age and Optacon reading speed. This variable was also included in the present analysis. As early as 1970, there was some interest in the possible influence of past visual memories on Optacon reading (Baer and Hill, 1972). This variable was used by Tobin in his Optacon evaluation. Based on a subjective feeling that it might have some effect, sex was also considered as a factor.

Measuring Variables

Age, sex, and age of onset of blindness were determined by a questionnaire. Braille reading speed is tested on the first day of class. Each student works in a separate room and on a one-to-one basis with his instructor. The student is given three short stories in standard grade 2 braille. He reads each story silently. The instructor checks for comprehension and, using a stopwatch, records the time it takes to read each story. After classes are finished, the three times are used to compute the average braille reading speed for each student.

Letter recognition and Optacon reading speed are measured on the final day of training. Again, the instructor works alone with the student. As in training, a Visual Display is connected to the Optacon so the instructor can monitor the student's performance. Reading speed is tested using a five-paragraph story. The teacher reads the first paragraph aloud. The second is read aloud by the student with the instructor helping him when necessary. At this point, the student should have some idea of the context of the story. He then reads the remaining three paragraphs silently with the instructor recording the time taken for each. These three times are later used to compute the average reading speed. As with the braille test, the teacher checks for comprehension.

Letter recognition is tested using exercises from the training material. Specifically, a criterion test from Lesson 9 is used for upper case letters and one from Lesson 20 for lower case. The student moves the camera himself as he identifies each letter. The instructor records his answer without telling the student whether or not it is correct. There is no time constraint and the student may only scan each letter one time. The percentage of letters correctly identified is used as the letter recognition score.

Using standard estimators, the means and standard deviations for these variables were calculated. The value "1" was used for a male and "0" for female. Table 3 summarizes the information about the sample.

TABLE 3

Characteristics of TSI Student Population

Factors	Mean	Standard Deviation
Age (years)	30.12	9.57
Sex	0.707	0.461
Age of Onset of Blindness (years)	5.63	10.62
Braille Reading Speed (words/min)	101.35	48.38
Optacon Reading Speed (words/min)	9.61	4.65
Letter Recognition (percent correct)	0.931	0.051

Distributions of the Measured Variables

To perform an analysis of variance on either Optacon reading speed or letter recognition, that variable must be normally distributed.

Chi-squared goodness or fit tests were used to check this hypothesis. Optacon reading speeds ranging from zero up to 20.22 words-per-minute were observed at the end of the training course. For the chi-squared test, the interval from zero to 22 was divided into 11 equal two-unit segments. The hypothesis tested is that, on this interval, Optacon reading speeds are normally distributed with estimated means of 9.16 and standard deviation of 4.65.

Table 4 shows both the observed and predicted number of reading scores in each interval. The predicted numbers have been adjusted so that the normal distribution is completely restricted to the interval from zero to 22.

TABLE 4

Histogram of Optacon Reading Scores

Interval	Observed	Predicted
0 - 2	1	1.58
2 - 4	4	3.02
4 - 6	8	4.84
6 - 8	6	6.45
8 - 10	7	7.17
10 - 12	3	6.65
12 - 14	6	5.13
14 - 16	3	3.30
16 - 18	1	1.77
18 - 20	1	0.79
20 - 22	1	0.30

Based on these figures, the calculated chi-squared statistic is 6.832 with eight degrees of freedom. At the five percent level, the predicted chi-squared equals 15.507 so the hypothesis is accepted at this level. In fact, the hypothesis is finally rejected at the 70 percent level where chi-squared equals 5.527. This suggests that the hypothesis of a normal distribution is very strong.

Letter recognition test scores ranged from 0.500 up to 0.993. All but four of the people tested had scores between 0.900 and 1.000. The interval 0.500 to 1.000 was divided into seven unequal intervals so that most of the intervals could be in the range where most people scored. The hypothesis is that letter recognition scores are normally distributed with an estimated mean of 0.931 and standard deviation of 0.051. Table 5 summarizes the observed and predicted number of scores in each interval. Again, the predicted values have been adjusted to restrict the normal distribution to the interval being tested.

TABLE 5

Histogram of Letter Recognition Scores

Interval	Observed	Predicted
0.50 - 0.80	1	0.23
0.80 - 0.90	3	11.96
0.90 - 0.92	8	6.39
0.92 - 0.94	9	7.30
0.94 - 0.96	7	6.32
0.96 - 0.98	7	5.21
0.98 - 1.00	6	3.60

From these figures, the calculated value of the chi-squared statistic is 12.380 with 4 degrees of freedom. At the five percent level, the predicted value of chi-squared is 9.488, so the hypothesis of normal distribution is rejected. The hypothesis would be accepted at the one percent level where chi-squared is 13.277.

Another area to be tested is the statistical independence of the letter recognition and Optacon reading speed variables. A chi-squared test of this gives a chi-squared value of 86.394. The predicted value of chi-squared at the five percent level is 79.082 with 60 degrees of freedom. The hypothesis is rejected at this level. It would finally be accepted at the one percent level where chi-squared is 88.379.

Since letter recognition is neither normally distributed nor independent of Optacon reading speed, it did not seem appropriate to include in further analysis.

Correlation Coefficients

In the regression analysis, a set of linear equations is solved to yield the coefficients. In solving these equations, it is helpful to the analysis of variance if the factors most likely to be statistically significant are solved for first. The correlation coefficients have been calculated in an attempt to get a rough measure of the significance of each factor. The factors will be ordered according to which one has the largest absolute value of its correlation coefficient. These correlations are also of interest in themselves as they sometimes disagree with the results of analysis of variance.

The standard estimator for the correlation coefficient has been used. This estimator is derived from the bivariate normal distribution. The t statistic is used to test the hypothesis that the correlation coefficient is statistically equivalent to zero. The variable for Optacon reading speed has already been shown to have a normal distribution. Although tests have not been made, it appears that age and braille reading speed are also normally distributed. On the other hand, the distribution of sex within the sample has a demonstrably binomial form. An examination of the data also suggests that age of onset of blindness would probably have a distribution represented by a decaying exponential. In this case, the correlation coefficients and the statistical tests on them are only a very rough guide to the significance of these factors.

Table 6 shows the correlation with reading speed and the calculated t statistic for each factor.

TABLE 6

Correlations with Optacon Reading Speed

Factors	Correlation Coefficient	t
Age	- 0.6047	4.74
Sex*	- 0.3248	2.14
Age of Onset of Blindness	- 0.3441	2.19
Braille Reading Speed	0.0672	0.402

*Negative value indicates that females had higher reading scores.

The equation for the regression analysis will be ordered as in the table above. Although the coefficient for age of onset of blindness has a slightly larger magnitude, sex was solved for first on the basis of an earlier analysis and with a smaller sample.

All of the t statistics have 39 degrees of freedom. At the five-percent level, the t distribution has the value 1.685. From this, it appears that only for braille reading speed would the hypothesis of a zero correlation be accepted. Braille reading speed would become significant at the 40-percent level where t equals 0.255. At the one-percent level, t equals 2.426. Hence, sex and age of onset of blindness would have zero correlation at this level. At the 0.05-percent level, t equals 3.561 so that age still has a non-zero correlation.

Regression Analysis

To construct a linear model for Optacon reading speed, coefficients of the normal equations had to be calculated. For a number of reasons, it seemed better to break each factor up into a set of variables which take the values zero and one only. The definitions of the controllable variables are given below.

Age. From earlier analysis with a smaller sample, it was clear that there was an extremely sharp break between people above the mean age and those below it. It seemed reasonable then to use a set of discrete levels to more accurately represent the situation. These variables take the value one in the indicated age range and are zero otherwise as follows:

z_{11} those under 20 years of age

z_{12} those between 20 and 30

z_{13} those between 30 and 40

z_{14} those over 40

The reading speeds within each of these age ranges appear to be more consistent than would be the case with a smaller number of levels.

Sex. This factor has an obvious two-level representation. For this analysis as for the correlation coefficients:

$$z_2 = \begin{cases} 1 & \text{for male} \\ 0 & \text{for female} \end{cases}$$

Age of onset of blindness. This factor was divided into three levels. These levels were based on the point in education at which people became blind.

z_{31} those blinded early in their education, under 10 years of age

z_{32} those blinded during the main part of their education process, between 10 and 25

z_{33} those blinded after the major portion of their education, over 25

Braille Reading Speed

z_4 those at or below the mean braille reading speed

Using these variables, the matrix which results from the normal equations is as follows:

3.61	-1.95	-1.17	-0.49	0.17	-0.32	0.71	-0.39	-0.15	20.74
-1.95	10.24	-5.85	-2.44	-3.15	1.41	0.54	-1.95	2.27	33.07
-1.17	-5.85	8.49	-1.46	1.51	0.05	-0.88	0.83	-1.44	-28.76
-0.49	-2.44	-1.46	7.39	1.46	-1.15	-0.37	1.51	-0.68	-25.70
0.17	-3.15	1.51	1.46	8.49	-2.05	0.88	1.17	-4.56	-27.86
-0.32	1.41	0.05	-1.15	-2.05	5.80	-2.49	-3.32	3.76	12.90
0.71	0.54	-0.88	-0.37	0.88	-2.49	2.78	-0.29	-1.61	6.32
-0.39	-1.95	0.83	1.51	1.17	-3.32	-0.29	3.61	-0.02	-22.11
-0.15	2.27	-1.44	-0.68	-4.56	3.76	-1.61	-0.02	10.20	8.32

The first term of the linear model is equal to the mean 9.16. When the matrix is solved, the resulting linear model for Optacon reading speed, x, is:

$$x = 9.16 - 2.84\,(z_{11} - 0.098) - 6.72\,(z_{12} - 0.488) - 10.46\,(z_{13} - 0.293) - 13.31\,(z_{14} - 0.122) - 0.74\,(z_2 - 0.707) - 2.18\,(z_{31} - 0.829) - 2.36\,(z_{32} - 0.073) - 3.83\,(z_{33} - 0.098) + 0.08\,(z_4 - 0.0537)$$

Analysis of variance. It is possible that some of the factors solved for do not, in fact, help in predicting the person's reading speed. The analysis of variance technique can be used to determine if some of the coefficients are statistically equivalent to zero. The technique involves the division of the sum of squares into parts corresponding to each variable. The remainder is the error term and can be used as an estimator for the standard deviation of the error distribution. Table 7 gives the results of the analysis of variance.

TABLE 7

Analysis of Variance of Optacon Reading Speed Predictors

SS is the sum of squares. DF is the degrees of freedom which is the number of variables representing a factor in the normal equations. MS is the mean square and is the SS entry divided by the DF entry. F is the ratio of the MS entry for the error term.

Factor	SS	DF	MS	F
Mean	3440.13	1		
Age	363.64	4	90.91	6.09
Sex	21.00	1	21.00	1.41
Age of Onset of Blindness	18.50	3	6.17	0.42
Braille Reading Speed	0.03	1	0.03	0.002
Error	462.55	31	14.92	

If a particular factor is such that all of the coefficients in the linear model are zero, the F entry should be small relative to the predicted value from the F distribution. For braille reading speed $F \frac{1}{31} = 4.16$ at the five percent level so that the hypothesis that braille reading speed does not predict Optacon reading speed is accepted. For age of onset of blindness, $F \frac{3}{31} = 2.91$ so that this factor is also not significant at the five percent level. For sex, the predicted value of F is the same as for the braille reading speed, 4.16, so that this factor is also insignificant. At the five-percent level, the predicted value $F \frac{4}{31} = 2.68$ so that the coefficients corresponding to age are statistically different from zero. In fact, they remain statistically significant up to the 0.1-percent level where $F \frac{4}{31} = 6.08$.

Since age is the only significant factor, the linear model for Optacon reading speed, x, is:

$$x = 17.27 - 2.84z_{11} - 6.72z_{12} - 10.46z_{13} - 13.31z_{14} + e$$

where e is the error term which has a normal distribution with mean zero and standard deviation 3.73.

Update of the Original Analysis

As mentioned above, data of the same kind used in the main analysis was also gathered from the March, April, and May classes of 1974. A total of 23 people were trained to use the Optacon during this time. For a number of reasons, primarily previous experience in using the Optacon, six of these people could not be used in a statistical analysis. The remaining 17 data points were added to the original 41 to compute a new mean of 10.00 and standard deviation of 5.18 for Optacon reading speed at the end of training. Because of the earlier analysis, it was assumed that age remained a significant factor in predicting Optacon reading speed. Therefore, the linear model for mean reading speed was updated. The resulting equation is:

$$x = 14.35z_{11} + 12.37z_{12} + 7.54z_{13} + 4.62z_{14} + e$$

where e, the error term, has mean zero and standard deviation of 4.29. This equation is graphed in Fig. 1 which illustrates the dramatic relation between age and Optacon reading speed at the end of the TSI training course.

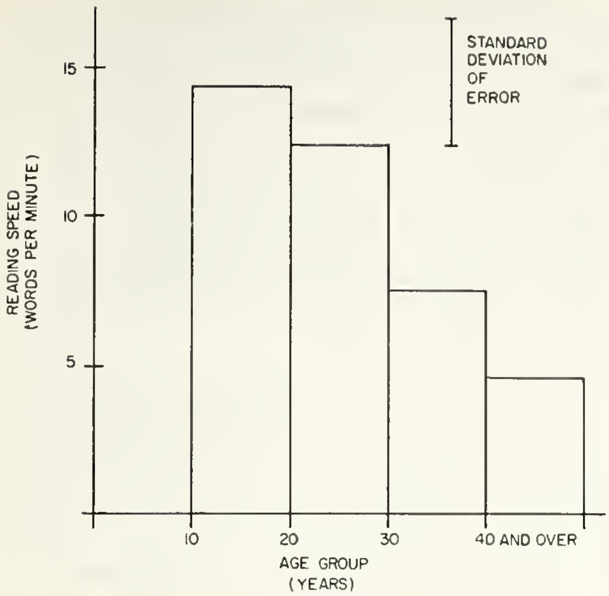

Figure 1. Optacon Reading Speed at the End of TSI Training Course as a Function of Age Group, Based on Data from 58 Students Between Mid 1973 and Mid 1974.

Effect of Teacher Experience on Student Performance

A question was raised concerning the effect of additional teacher experience on the student's performance. To test this, mean reading speeds from sample groups at the beginning and at the end of the data collection were compared. The test was based on the assumptions that 1) the underlying distribution of reading speeds was normal, and 2) the standard deviations of both samples, although unknown, were equal. These assumptions seemed reasonable in view of the previous analysis. Ten students from the first four classes were used for the early sample, and ten from the April and May classes were used as the last sample. The students in the first group had a mean reading speed of 9.86 words-per-minute, and the students in the last group had a mean reading speed of 13.35 words-per-minute. The computed value of the t statistic was -1.469. With 18 degrees of freedom, the predicted five-percent level of the t distribution is -1.734; hence, the hypothesis that mean reading speed of a later group is less than or equal to that of the early group is accepted. This hypothesis would be rejected at the 10-percent level where t equals -1.330. At this level, it would appear that the mean reading speed of the later group was statistically significantly higher than that of the early group.

Since age is known to be a significant factor, a t test under the same assumptions was used to determine if a significant difference existed in the mean ages of the two groups. The computed value of the t statistic is -0.758. Hence, there is no statistically significant difference between the mean ages of the two groups.

These two tests do not necessarily provide an absolute answer. However, based on them, it appears that no statistically significant change in mean reading speed has occurred as a result of additional teacher experience. A more detailed analysis of variance would be necessary to understand all of the effects and interactions between teacher experience and Optacon reading speed.

Implications of the Analysis

The most important result of this analysis is the negative correlation between the age of a person at the time of training and his reading speed at the end of that training. This does not imply that an older person cannot learn to read with the Optacon. It simply states that the average reading speed that can be expected at the end of training will be lower. There is, however, a reasonable probability that a person in a given age group will read more quickly or more slowly than the predicted mean. It may be that, for people over the age of 40, a less intensive, more extended period of training would be more appropriate. Also, any "screening" test which attempts to predict a person's performance in Optacon training will have to take age into account as a concomitant variable. Otherwise, the effect of this factor may overwhelm the predictive value of the test itself.

The fact that letter recognition scores do not have a normal

distribution is, on reflection, not surprising. Reading with the Optacon at the end of training is a slow, almost letter by letter, process. In order to read, then, a person must be able to recognize individual letters. Even an experienced Optacon reader may be forced to examine an unusually long or unexpected word in this manner. Perhaps a more appropriate mathematical model for letter recognition scores would be a Bernoulli trial: that is, either the person recognizes letters or he does not. In light of these remarks, the interdependence between Optacon reading speed and letter recognition should be expected. The surprising part is the marginal quality of that relationship.

The correlation between sex and Optacon reading speed was statistically significant. Yet, the analysis of variance showed that this factor had no predictive value. The disagreement in the results obtained from these two methods of analysis can be explained in terms of the effect of age on performance. The average age of the women was 26.5 years while that of the men was 31.6 years. These means are on opposite sides of the population mean which is the most significant breakpoint for Optacon reading speed. As mentioned before, the probability of a certain number of men in a sample is given by a binomial distribution. The probability of choosing a man at random in the entire U.S. population is 0.487. Using this value, the probability according to the binomial distribution of 29 or more men in a random sample of 41 people is 0.00355. This would suggest that people selected by the method of Optacon purchase has not been a random process. Those women who have obtained Optacons have, on the average, been younger.

There is an even simpler explanation for age of onset of blindness having a statistically significant correlation with reading speed but not being a significant factor in a predictive model. The older a person is when he becomes blind, the older that person has to be when he is trained to use the Optacon. That is, it is a logical contradiction to have someone who lost his vision at 34 but is 25 when trained to use the Optacon. Again, the correlation coefficient is explained in terms of the significance of age.

Perhaps the most remarkable conclusion to come from this analysis is the complete lack of significance of braille reading speed. As indicated earlier, it was thought that this variable might give some indication of tactile sensitivity. Apparently, it does not. Weisgerber, et al. (1974) obtained the same result. Tobin, et al. (1973), however, did find a statistically significant relationship between this variable and Optacon reading speed.

Even with age as a factor, the error term in the predictive model has a relatively large standard deviation. This implies that predictions based on this model are relatively uncertain. TSI has developed an assessment test battery which measures short-term memory, manual dexterity, and tactile sensitivity. To date, the effectiveness of this test as a predictor of performance in Optacon training has not been statistically analyzed. Hopefully, this test or some similar instrument can be developed to help assess a person's potential for effective use of the Optacon.

PART III—USE OF THE OPTACON ON THE JOB

Part I gives some idea of the occupations where the Optacon can be used as an effective tool. To try to find out how people in different occupational groups actually use the Optacon, a telephone survey was conducted. A total of 17 people were interviewed in this manner. An attempt was made to get two people from each of the major categories shown in Table 1, Part I.

The questions asked were intended to determine the amount of time the person used the Optacon each day, the kinds of materials read, and the importance of the Optacon to the person in performing his job. Information was also gathered about use of the Optacon outside of the job, estimated reading speed, and some other details about age and Optacon training. The following are brief summaries of these telephone interviews.

<u>Respondent 1.</u>

Age estimated--24-25

Age of onset of blindness: unknown, apparently early

Optacon training center: Vision Center of Central Ohio, Inc.

Date of training: March 1974

The respondent is currently in training to be a medical transcriber. She has already graduated from college with a bachelor's degree in linguistics. Due to the recent date of her training with the Optacon, she has not been able to make full use of it. She intends to use it as a selling point when seeking employment. Currently, she uses it to read dictionaries, personal correspondence, and other similar personal materials. She is also using the Optacon to learn to read different alphabets such as Greek and Arabic. She indicated that Arabic presented serious difficulties. Her reading speed at the end of training was 20 words per minute; she would not give an estimate of her present reading speed.

Respondent 2.

Age: 20

Age of onset of blindness: 3

Optacon training center: San Diego Unified School District

Date of training: December 1971

He is currently majoring in business administration and Spanish. He uses the Optacon to read hand-outs of class materials, announcements, and some brief passages of text. During the last school year, he used the Optacon to read all of the materials for a course in Spanish grammar. He indicated that he was able to do this sufficiently well to complete the course with a high grade. He is very interested in using the Optacon with a pocket calculator as he believes this will help him in his business courses. He estimates his reading speed to be in excess of 40 words-per-minute, and says that he reads with it from an hour- to an hour-and-a-half-per-day. Outside of class, he uses it to read personal correspondence and materials from groups in which he participates. He will attend law school after graduation and plans to use the Optacon extensively during his studies. He states that he is very dependent on the Optacon and would feel lost without it.

Respondent 3.

Age: 26

Age of onset of blindness: 26

Optacon training center: TSI

Date of training: June 1973

The respondent is currently studying for a master's degree in social work. She uses the Optacon to read a wide variety of materials necessary in her studies. She depends on the Optacon to read class handouts, notes, tests, and some texts. She indicated that the Optacon has been extremely useful in proofreading her typing of reports and papers. She believes she uses the Optacon for an average of two hours-per-day. She estimates her reading speed at 40 words-per-minute.

During her internship work at a hospital, she used the Optacon to review charts and write-ups of previous interviews with patients. She also used the Optacon to read confidential case files. She felt that this was very important since it was difficult to obtain access to these files in any other way. She does not feel she could function in graduate school or in an employment situation without the Optacon. Her ability to use the Optacon will help her to obtain a job.

Respondent 4.

Age: 38

Age of onset of blindness: birth

Optacon training center: Prof. Robert Stilwell, Morgantown, West Virginia

Date of training: early 1973

Respondent is a professor of political science currently using the Optacon an hour or more each day. His reading speed is between 40 and 50

words-per-minute. He uses the Optacon for several tasks related to his university work (memos, circulated articles, etc.), but would like to increase his speed. He seemed interested in the typewriter attachment as he uses the Optacon to proofread his work. He reads term papers and theses and can easily understand the organization and thoroughness of a student's research from looking at the format.

He does not feel dependent on the Optacon to do his job as he was in the same position prior to getting the machine. However, he does feel he now works more effectively and can read certain materials more quickly and organize his work more effectively.

Respondent 5.

Age: 38

Age at onset of blindness: birth

Date of training: December 1973

Optacon training center: TSI

Respondent currently works as an elementary school teacher. She uses the Optacon about four hours-per-day and estimated her reading speed at 40 to 45 words-per-minute. She reads job-related material (memos, teacher's editions of textbooks) and personal items. Because elementary textbooks are frequently changed, the teacher's editions are often unavailable in other form. She uses the Optacon to find supplementary materials for the basic textbook of the course. She feels that scanning these materials is one of the most important benefits to her. She also uses the Optacon for work which she takes home from school and feels strongly that she is a better teacher because of the Optacon, and wonders how she managed without it before.

Respondent 6.

Age: 29

Age of onset of blindness: birth

Optacon training center: TSI

Date of training: November 1972

Respondent works as a programmer for an oil company and uses the Optacon three or four hours-per-day. She estimated her reading speed at 50 to 60 words-per-minute but felt that the speed was not terribly important--it is sufficient to allow her to do her job. She reads nearly all the materials for her job with the Optacon (computer listings, program specifications, computer manuals, memos). She also uses the Optacon with a CRT terminal, but usually cannot read handwritten material. She mentioned that the Optacon had not been a strong selling point when she obtained her current job but the independence and flexibility conveyed by its possession may have helped convince her employer to hire her.

Respondent 7.

Age: 28

Age of onset of blindness: 4

Optacon training center: Vision Center of Central Ohio, Inc.

Date of training: end of 1973

Respondent works as a computer programmer for the State of Ohio, uses the Optacon four to six hours-per-day, and estimates his reading speed at 40 to 45 words-per-minute. Although he has the option of receiving braille output from the computer, he uses the Optacon to read computer listings, program specifications, computer manuals, memos and notices, and only uses braille when he must scan a lengthy program written by someone else. At present, he feels he can skip between widely separated sections of a program more easily in braille; he can scan with the Optacon if necessary.

He had his present job before obtaining the Optacon but now feels he is very dependent on the machine to do his job properly and without it he would not be nearly as productive.

Respondent 8.

Age: 35-40

Age of onset of blindness: unknown

Optacon training center: unknown

Date of training: 1972

Estimates he uses Optacon about two hours-per-day on the job and has a reading speed of 20 to 25 words-per-minute. He uses the Optacon to look up information in references and to read correspondence. He would like to be able to read pocket calculators and would also like to look at an oscilloscope display and other measuring instruments. He did not feel the Optacon was necessary in his job as he had the job before obtaining his Optacon; however, he did suggest that he now works more efficiently.

Respondent 9.

Age: 33

Age of onset of blindness: birth

Optacon training center: TSI

Date of training: December 1972

Respondent works as an electrical engineer and uses his Optacon approximately two hours-per-day on the job. He works primarily as a technical writer and estimated his reading speed at 40 to 70 words-per-minute. He uses the Optacon to read inter-office materials, technical reports, references, to proofread his typing, examine circuit diagrams and amateur radio manuals. His reading speed is higher in braille, but often the materials he needs are not transcribed. He is therefore very dependent on the Optacon in his job, has no readers on his staff, and is not getting materials transcribed in any other way. He feels the Optacon is sufficient in his job.

Respondent 10.

Age: 31

Age of onset of blindness: birth

Optacon training center: TSI

Date of training: April 1974

Respondent works as a lawyer for a large automobile manufacturer. He uses the Optacon one-half to one hour-per-day and estimated his reading speed at 25 words-per-minute. He uses the Optacon primarily to read summaries of court decisions, usually found in a weekly or biweekly journal. He reads his correspondence when his secretary is not available, but hopes to make better use of the Optacon as his reading speed increases. He also uses the Optacon for pleasure reading, such as sports news in the newspaper. This is not readily available to him in other forms. Since he was unable to use the Optacon for almost a month, his reading speed was probably inhibited. He does not feel the Optacon is essential for his job at this time but said that if his reading speed were faster he would become more dependent on it. He values the independence the Optacon gives him.

Respondent 11.

Age: 28

Age of onset of blindness: birth

Optacon training center: Cleveland Society for the Blind

Date of training: November 1972

Respondent works as a lawyer in a small law firm. He uses the Optacon about four hours-per-day, frequently much longer, and estimated his reading speed at more than 50 words-per-minute. He uses the Optacon for almost all reading done on the job (trust agreements, federal statutes, law journals, contracts, correspondence), but prefers longer materials to be read to him. He is completely dependent upon the Optacon in his job and could not have obtained his present job without it. He enjoys the independence the Optacon gives him.

Respondent 12.

Age: 24

Age of onset of blindness: birth

Optacon training center: TSI

Date of training: May 1974

Respondent currently works as a dictaphone typist for the Canadian Government and uses the Optacon about one hour-per-day. She estimated her reading speed in excess of 20 words-per-minute and stated that she uses the machine to look up words in the dictionary and to proofread. She believes the Optacon was helpful in obtaining her job. Her ability to read print without assistance probably helped convince her employer. She now feels she could not do her present job without the Optacon.

Respondent 13.

Age: 46

Age of onset of blindness: 12

Optacon training center: TSI

Date of training: May 1974

Respondent is currently an administrator in a vocational rehabilitation department. He uses the Optacon one-half to one hour-per-day and estimated his reading speed at 15 to 20 words-per-minute. He uses the Optacon mainly as a sorting tool for correspondence at work and reads short material, such as one-page memos and correspondence, when his secretary is unavailable. He does not really need the Optacon to do his present job, but feels it makes him more efficient and organized. He likes the added independence it gives him.

Respondent 14.

Age: 40

Age of onset of blindness: mid-20's

Optacon training center: unknown

Date of training: summer 1973

Respondent is currently employed as a supervisor of caseworkers in an agency for the blind. He uses the Optacon about one-half hour-per-day on the job and estimates his reading speed at 15 to 20 words-per-minute. He uses the Optacon primarily to sort incoming correspondence, but also reads confidential personnel files. He feels he could handle his job without the Optacon as he obtained the job before obtaining the Optacon. However, he believes he can work more efficiently with it.

Respondent 15.

Age: 41

Age of onset of blindness: 21

Optacon training center: TSI

Date of training: January 1973

Respondent works as a high school counselor in California and uses the Optacon about two hours-per-day. He estimated his reading speed at 25 to 30 words-per-minute and stated that he uses the Optacon primarily to read books and extended articles to keep himself up to date. For shorter articles, he uses readers and/or his secretary. He feels it would be difficult to work without the Optacon and as his reading speed increases he hopes to use it for more of his job-related reading. He greatly values the independence the Optacon gives him.

Respondent 16.

Age: 40

Age of onset of blindness: 36

Optacon training center: self-trained

Date of training: December 1973

Respondent is employed as a counselor in the psychological section of the Veterans Administration. He uses the Optacon three or four hours-per-day in job-related activities and estimated his reading speed at 60 words-per-minute. He uses the Optacon to read almost all of his job-related reading as well as material related to his thesis, to draw and read flow charts, and to proofread when he types. He firmly believes he could not do his job without the Optacon as he would be much less efficient and productive. He values the independence the Optacon gives him.

Respondent 17.

Age: 39

Age of onset of blindness: birth

Optacon training center: TSI

Date of training: February 1974

Respondent works in the personnel department of a large chain store and uses the Optacon an hour to an hour and a half each day. He uses the machine to read short memos, telephone numbers, and journals such as the *Journal of Rehabilitation*, and estimates his reading speed at 15 to 20 words-per-minute. He recently used his Optacon to analyze information on job applications rather than have his secretary do it. Although he had the job before obtaining the machine, he feels he is able to work more efficiently now. He greatly appreciates the added independence the Optacon brings him.

Conclusions

The interviews suggest that the people who are making most effective use of the Optacon on the job are the younger people in entry-level positions. This can be partly explained by the fact that younger people learn to use the Optacon more rapidly. Also, for people in entry level positions, it seems to be more important to demonstrate a capability in advance in order to be able to perform the job with a minimum of additional expense to the employer. Older people have, in general, already worked out alternative methods for obtaining information. They are usually in positions with high enough rank that the employer is willing to spend the additional money for readers or special equipment. These individuals, therefore, do not have the incentive to perform their jobs without special assistance. This implies that those people who are most able and willing to use the Optacon have not been the major group obtaining access to it. It seems imperative to find some means to allow younger people to obtain Optacons; this would permit them to compete more effectively for entry-level positions.

Even for people who are not able to read as quickly with the Optacon, it seems to give them an opportunity to organize their materials and time more efficiently. It permits them to choose which materials to have read or brailled and which to ignore. It also allows them to handle shorter passages of reading independently while their secretary or assistant is working on more lengthy materials. These individuals can deal privately with confidential material which can be of considerable importance to people in senior administrative positions. With these people, the Optacon, although not "necessary," can be a tool which makes it possible for them to become more efficient and more productive employees.

SUMMARY

The first part of this paper indicates that, since mid-1973, more young people have been able to obtain Optacons. This is apparently a result of large-scale Optacon dissemination programs such as that of the Richard King Mellon Foundation. It also indicates that blind people in a wide variety of jobs have felt that the Optacon can significantly increase their efficiency as an employee. This conclusion is substantiated by the interviews conducted with Optacon users. Some of these people indicated that they could not have obtained their present jobs without it. Others indicated that, although not essential to their employment, the Optacon made them more efficient, better organized workers.

These interviews strongly suggest that the Optacon, as an employment tool, cannot be limited to a small set of occupations. Instead, it should be considered as a useful tool in any job where retrieval of printed information is essential.

The statistical section of this paper indicates that young people read more quickly at the end of Optacon training than do older people. The interviews show that young people are also more dependent upon it in their employment. The Optacon has given them the ability to do a job without special concessions from their employer. Many of the people interviewed

expressed the belief that this made it possible for them to obtain a job or to advance within their present organization. In short, many young people in entry-level positions have found the Optacon to be absolutely essential.

REFERENCES

Baer, J. A., & Hill, J. W. *Optical-to-tactile image conversion for the blind.* Final Report on Contract SRS 70-42 and Grant 14-P-55296/9-02 for Social and Rehabilitation Service, U.S. Department of Health, Education and Welfare. Stanford Research Institute, Menlo Park, California, June 1972.

Bowker, A. H., & Lieberman, G. J. *Engineering statistics.* Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1959.

Fraser, D. A. S. *Statistics--An introduction.* New York: John Wiley & Sons, Inc., 1958.

Goldish, R. H., & Taylor, H. E. The Optacon: A valuable device for blind persons. *The New Outlook for the Blind*, February 1974.

Teaching Guidelines (R17454-B). Telesensory Systems, Inc., Palo Alto, California, 1974.

Tobin, M. J., James, W. R. K., McVeigh, A., & Irving, R. M. *Print reading by the blind--An evaluation of the Optacon and an investigation of some learner variables and teaching methods.* Research Centre for the Education of the Visually Handicapped, School of Education, University of Birmingham, 1973.

Weihl, C. The Optacon reading program at Monroe Public School. *The New Outlook for the Blind*, May 1971.

Weisgerber, R. A., Everett, B. E., Rodabaugh, B. J., Shanner, W. M., & Crawford, J. J. *Educational evaluation of the Optacon (optical-to-tactile converter) as a reading aid to blind elementary and secondary students.* AIR-34500-9/74-FR. Submitted to Bureau of Education for the Handicapped, U.S. Office of Education, Washington, D.C., under Contract No. OEC-0-72-5180. Final Report, September 1974.

SPELLED SPEECH AS AN OUTPUT FOR THE LEXIPHONE READING MACHINE AND THE SPELLEX TALKING TYPEWRITER

Ching Y. Suen*

Michael P. Beddoes**

Abstract: This paper studies the applicability of a synthesized spelled speech code for two types of speech aids for the blind: the Lexiphone reading machine and the Spellex talking typewriter. In the investigation of the perception of the spelled speech code, both the intelligibility of letter sounds and the effect of bandwidth variation were examined. The results indicated that all 26 synthesized letter sounds were recognizable at a bandwidth as low as 3 kHz. after a short period of training.

The effects of presentation speed, bandwidth, word length, and pause between words on the intelligibility of spelled sentences were also investigated using a computer simulated Lexiphone. Experimental results indicated that an ordinary young blind subject could read sentences spelled out at 65 to 75 words-per-minute with a high intelligibility score. Reduction in bandwidth, increase in presentation speed, and increase in word length, all reduced the intelligibility of spelled speech. It was also found that a pause proportional to the length of the preceding word instead of a fixed one did not increase intelligibility appreciably. The application of the high-speed spelled-speech code to the Spellex talking typewriter improved the accuracy of blind typists and in many cases also improved their typing speed.

*Department of Computer Science, Sir George Williams University, Montreal, P.Q., Canada H3G 1M8.

**Department of Electrical Engineering, University of British Columbia, Vancouver 8, B. C., Canada.

INTRODUCTION

"How can one develop a set of alphabet letter sounds on tape for a reading machine for the blind or for other instruments requiring an auditory readout?" The work of Metfessel (1963) and Metfessel and Lovell (1961 and 1972) indicated in general terms an answer to this question. Their aim was to produce a set of distinctive sounds very brief in duration for each letter of the alphabet in order to facilitate a high reading rate. The letter sounds were to be concatenated to form easily readable words and sentences. Using the tape recorder as the chief tool, they described many techniques for removing redundant parts of the letter sounds by the cut-and-splice method. In this pruning operation they attempted to minimize discontinuities within letters and between letters. The task was difficult and time consuming, but Metfessel and Lovell came up with a set of alphabet sounds which needed broad-band equipment and very low distortion before subjects could read well. Work by Beddoes (1963) used a different scheme to shorten the durations of the letter sounds. Samples were removed from original recordings in a random fashion, and even so, comparable reading rates (about 80 to 100 words-per-minute) were obtained.

All the above work was based on analog principles and was directed more to test the idea of spelled speech, in particular how quickly blind people could read with it, than to develop a good machine to generate the spelled speech sounds; the

technology for which was not ready at the time. As we see it now, digital circuits are preferable to analog ones in the development of speech aids for the blind because of their compactness, high speed of operation, and repeatability. Although digital sampling will introduce a certain amount of quantizing noise, this effect can be minimized using high-resolution converters.

Assuming we store speech in digital form, it is essential to minimize the number of bits of samples in order to cut down the cost. Several methods were employed to achieve this goal. First, vowels are quasiperiodic. By repeating the pitch period (60 to 120 digital samples at 12.5-kHz sampling) 10 to 20 times, lifelike vowels were produced. Second, speech samples were economically stored as differences rather than their absolute magnitudes. Third, since letter sounds can be synthesized by concatenation of phonemes, only a limited number of phonemes rather than the entire set of alphabet sounds were stored. Using these and other techniques, the spelled speech code shown in Table 6 has been developed with the aid of a computer (Suen, 1972; Suen and Beddoes, 1973). It consists of only 18 basic phonemes, namely, /b/, /s/, /d/, /dz/, /k/, /p/, /t/, /v/, /w/, /i/, /e/, /ɛ/, /ɑ/, /o/, /u/, /ℓ/, /m/ and /n/. This code has a maximum output rate of about 120 words-per-minute. The construction of a digital spelled speech generator for incorporation in the reading machine and the talking typewriter was found to be economically viable (Suen and Beddoes, 1973). Experiments indicated that spelled speech is suitable for both machines. Further, it was shown that, although synthesized speech does not generally sound very "natural," the subjects required only a short period of training to master the code.

PERCEPTION OF THE SPELLED SPEECH CODE

Perception of the spelled speech code was studied at the following bandwidths: 3 kHz, 4 kHz, 5 kHz, and 6 kHz. Sixteen blind subjects, aged 14 to 27, in eight groups, took part in the experiment. Most of the subjects were students of the University of British Columbia. Except for the few subjects who had been blind for only a few years, the majority of subjects had acquired a good knowledge of Braille (with an average reading speed of 90 words-per-minute). All subjects were individually trained and tested.

This experiment was divided into two sessions of about one and a half hours each. At the beginning of the first session, the entire set of letter sounds was presented in random order to the subject for identification. The purpose was to find out how natural and distinct the synthesized letter sounds were. Four subjects were tested for each bandwidth. The result of this part of the experiment furnished scores which indicated the subjects' proficiency at identifying the synthesized letter sounds before training. Following this, the subject was taught to recognize the letter sounds at the 6-kHz bandwidth. Subsequently the subject was given control of the keyboard of the teletype so that any letter sounds could be heard by striking the corresponding keys. In this way, he learned to compare and contrast letters which could be easily confused. Short quizzes on letter identification were given to the subject from time to time. In the course of the experiment, the bandwidth was gradually reduced to 3 kHz and words and sentences were also introduced at a gradually increasing speed. By the end of this session, most subjects could recognize all the letter sounds and had been exposed to all four bandwidths and four speeds. The emphasis of the second session was on sentence reading though letter sounds were also reviewed from time to time. At the end of the second session, the subject was given a letter test to evaluate letter distinctiveness and learning effects.

The results of this experiment are shown in Tables 1 through 5, in the form of confusion matrices. The total scores (out of 104) for each bandwidth are: 57 at 3 kHz, 70 at 4 kHz, 64 at 5 kHz, and 64 at 6 kHz. The average score is 63.75, or 61.3 percent correct.

TABLE 1

Confusion Matrix of Letter Sounds at 3-kHz Bandwidth

Stimulus \ Response	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	3				1																					
B		4																								
C			1				1													2						
D		2		2																						
E		2			2																					
F						3													1							
G							4																			
H								4																		
I									3									1								
J							4																			
K							1			1						1				1						
L						1						1		2												
M														4												
N														4												
O															4											
P																4										
Q																4										
R	1																	3								
S	1					1								1					1							
T																2				2						
U		2			2																					
V		1																		2		1				
W									3														1			
X																								4		
Y																									4	
Z						1													1							2

TABLE 2

Confusion Matrix of Letter Sounds at 4-kHz Bandwidth

Stimulus \ Response	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	3				1																					
B		2														2										
C			3																	1						
D		2		2																						
E	1				3																					
F						4																				
G							3													1						
H								4																		
I									4																	
J							1			3																
K											3									1						
L						1						3														
M						1							1	2												
N														3					1							
O															4											
P																3				1						
Q																3				1						
R																		4								
S																			4							
T																				4						
U		1			3																					
V							1									2						1				
W									2														2			
X																			1					3		
Y																									4	
Z						1					1	1							1							

TABLE 3

Confusion Matrix of Letter Sounds at 5-kHz Bandwidth

Stimulus \ Response	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	2				2																					
B		1		1	1											1										
C			1																	3						
D				2												2										
E					4																					
F	1					3																				
G							3													1						
H								4																		
I									3									1								
J							3			1																
K					1						1					1				1						
L												3		1												
M														4												
N														4												
O															4											
P																4										
Q																2				2						
R																		4								
S																			4							
T																				4						
U					3																1					
V			1	1			1									1										
W									3														1			
X																			1					3		
Y																									4	
Z	1																									3

TABLE 4

Confusion Matrix of Letter Sounds at 6-kHz Bandwidth

Stimulus \ Response	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	2				2																					
B		4																								
C			3																	1						
D				3												1										
E		1			2																1					
F						3													1							
G							3													1						
H								4																		
I									4																	
J							3													1						
K							1			1						1				1						
L												1		3												
M	1													3												
N														4												
O	1				1										2											
P																4										
Q																4										
R									1									3								
S																			4							
T																1				3						
U					2																2					
V		1		1																		2				
W									2														2			
X																			1					3		
Y																									4	
Z	1					1																				2

TABLE 5

Combined Confusion Matrix of Letter Sounds for the Four Bandwidths

Stimulus \ Response	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	10				6																					
B		11		1	1											3										
C			8				1													7						
D		4		9												3										
E	1	3			11																1					
F	1					13													2							
G							13													3						
H								16																		
I									14									2								
J							11			4										1						
K					1		2			2	4					3				4						
L						2						8		6												
M	1					1							1	13												
N														15					1							
O	1				1										14											
P																15				1						
Q																13				3						
R	1								1									14								
S	1					1								1					13							
T																3				13						
U		3			10																3					
V		2	1	2			2									3				2		4				
W									10														6			
X																			3					13		
Y																									16	
Z	2					3					1	1							2							7

The combined scores shown in Table 5 indicate that some letters could be identified more easily than others. They also indicate that letters having the same phoneme sound at the beginning (such as /dʒ/ in letters G and J, and /ε/ in F, L, M, N, S, etc.) or at the end (such as /i/ in B, C, D, etc.) are more easily confused among themselves. Naturalness and distinctiveness of letters can be measured according to the identification scores gathered in this test. Letters ranked in this way are shown in Table 6. From this table, it can be seen that the synthesis (using /αεe/ of diphthong /αI/ which occurs in both Y and I was very successful. The low scores of U and Q indicate that direct combination of /i/ and /u/ does not give a good sound of diphthongs /ju/ and /IU/, which occur respectively in these two letters. The low scores of some other letters were mainly due to similarity in sound, such as the letter M was being misidentified as N (see Table 5), letter J mistaken for G, letter U mistaken to be E, etc.

TABLE 6

Combined Identification Scores of Letter Sounds in Descending Order of Correctness (Perfect Score: 16)

Score	16	16	15	15	14	14	14
Letter	H	Y	N	P	I	O	R
Sound	/eidʒ/	/wαεe/	/εn/	/pi/	/αεe/	/ou/	/α/
Score	13	13	13	13	13	11	11
Letter	F	G	S	T	X	B	E
Sound	/εV/	/dʒi/	/εs/	/ti/	/εks/	/bi/	/i/
Score	10	9	8	8	7	6	4
Letter	A	D	C	L	Z	W	J
Sound	/ei/	/di/	/si/	/εℓ/	/sε/	/dαbiu/	/dʒei/
Score	4	4	3	1	0		
Letter	K	V	U	M	Q		
Sound	/kei/	/vi/	/iu/	/εm/	/kiu/		

Although the identification scores of some letters (particularly U, M, and Q) seemed disappointingly low, it was found that after a short period of training, most subjects could identify all the letters without error.

During the progress of the experiment, it was observed that many subjects could easily learn to recognize all the letters correctly. In the letter test towards the end of the second session, each letter sound was presented five times in random order to the subject for identification. The results of this test are shown in Table 7. In this test, 12 subjects had perfect scores, 3 subjects made only 1 mistake out of 130 responses, and 1 subject made 8. Of the total number of 11 mistakes, 9 belonged to the 3-kHz bandwidth and 2 to the 6-kHz bandwidth. The extremely high 99.5-percent average correct identification score suggests that all letter sounds can be learned to perfect recognition after a short period of training. It also indicates that the intelligibility of the constructed set of letter sounds is highly resistant to bandwidth reduction.

TESTS ON A COMPUTER-SIMULATED LEXIPHONE READING MACHINE

In order to test the applicability of the spelled speech code to the reading machine, the Lexiphone was simulated on a PDP-9 computer. Sentences were typed and stored in the computer and spelled sentences were then generated for identification by the subjects.

The same 16 subjects were used in this test and this session lasted about one hour and a half. The factors investigated were divided into a number of treatment levels. Presentation speed was divided into four levels: 45, 55, 65, and 75 wpm. The bandwidths studied were 3 kHz, 4 kHz, 5 kHz, and 6 kHz. Two variations in pause duration after each word were examined; in one case the pause duration was fixed, and in the other it was made linearly proportional to the length of the preceding word. A Greco-Latin square design (Winer, 1962) was used in this experiment, the plan of which is shown in the Appendix. Four lists of phonetically balanced sentences (IEEE, 1969) were used. In each list, there were 74 words contained in ten unrelated sentences. Prior to each test, practice sentences were given to familiarize the subject with the test procedure. Test sentences were presented in the manner previously described in a pilot experiment (Suen and Beddoes, 1973) and there was a rest period of five minutes between lists. The results of this test are summarized in Tables 8 and 9.

It can be seen that the scores vary widely from subject to subject. A detailed analysis of the data showed that the subjects who were poor in Braille (particularly those who became blind in their adulthood), were also relatively poor in spelled speech; the results resembled those obtained from sighted subjects.* As a corollary, those who can read Braille well will also do well with spelled speech. We found a number of exceptional blind people who could read spelled speech comfortably at 80 words-per-minute.

Table 9 shows that the average scores of the blind subjects obtained were very high, ranging from 83 to 94.15 percent correct. It must be borne in mind that this was not merely an intelligibility test, but also partly a comprehension test because the subjects were tested on sentences rather than on single words. When subjects were questioned about content, they often showed that they understood the subject matter even when individual words were unintelligible.

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*A spelled speech experiment was conducted some time ago using a highly motivated group of sighted subjects (Suen and Beddoes, 1972). The same testing procedure and the same type of testing materials (PB sentences) were used. For approximately the same presentation speed (55 wpm in the present experiment with blind subjects and 54 wpm in the experiment with sighted subjects), the average percent correct score of the blind subjects was 12.93 percent higher than that of the sighted subjects'.

TABLE 7

Combined Confusion Matrix of Letter Sounds for the Four Bandwidths After Learning

Stimulus \ Response	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	80																									
B		80																								
C			80																							
D		2		77												1										
E					80																					
F						80																				
G							80																			
H								80																		
I									80																	
J										80																
K											80															
L												80														
M													78	2												
N														80												
O															80											
P																80										
Q																2	78									
R																		80								
S						2													78							
T																1				79						
U																					80					
V			1																			79				
W																							80			
X																								80		
Y																									80	
Z																										80

TABLE 8

Scores of Spelled Speech Experiment in Percent Correctness

		L_1	L_2	L_3	L_4
I_1	G_1	80.38	77.22	82.91	87.97
	G_2	95.57	79.11	85.44	76.58
	G_3	96.20	96.20	84.18	91.77
	G_4	88.61	93.04	96.20	99.37
I_2	G_5	84.08	79.11	90.51	90.51
	G_6	94.94	91.77	89.87	86.71
	G_7	92.45	98.10	89.87	90.51
	G_8	81.65	82.91	90.51	95.57

TABLE 9

Summary Data of Spelled Speech Experiment in Percent Correctness

List	L_1	L_2	L_3	L_4
I_1	90.19	86.39	87.18	87.92
I_2	88.31	87.97	90.19	90.82
Average	89.25	87.18	88.69	89.87
Speed (wpm)	a_1 (45)	a_2 (55)	a_3 (65)	a_4 (75)
I_1	93.51	89.87	87.66	81.65
I_2	94.78	91.30	86.87	84.34
Average	94.15	90.59	87.27	83.00
Bandwidth (kHz)	b_1 (3)	b_2 (4)	b_3 (5)	b_4 (6)
I_1	85.60	87.34	90.19	89.56
I_2	88.61	89.87	89.56	89.24
Average	87.11	88.61	89.88	89.40

An analysis of variance of the data indicates that: bandwidth and list of testing materials are both significant ($p < 0.05$), the speed of presentation is highly significant ($p < 0.01$), whereas both the row position and the interval of pause between words are not significant. The bandwidth effect is significant because lowering the bandwidth reduces the pleasantness and clarity of letter sounds. Since different lists of test materials contain words and sentences of varying lengths and familiarity, it is not surprising to find the list effect statistically significant. As expected, presentation speed is highly significant because the subjects had a shorter time to decode the sentences. The lack of statistical significance of row effect suggests that the order effect of subject groups in this test is not crucial. As far as the interval of pause between words is concerned, although a pause proportional to the length of the preceding word gives a slightly better result than a fixed interval (average score: variable interval, 89.32 percent correct; fixed interval, 88.17 percent correct), this effect is not significant at the 0.05 level.

Since presentation speed and bandwidth are the two factors in which we were most interested, further tests were made to probe the nature of differences among their treatment means. The results of Newman-Keuls' test are summarized schematically as follows:

Thus, it can be concluded that the effects of the four speeds of presentation on intelligibility differ significantly from one another. For the four bandwidths, only 3 kHz differs significantly from 5 kHz and 6 kHz. During the experiment, the subjects also often reported that the 3-kHz letter sounds were less pleasant than those having higher bandwidths.

The results of this experiment indicate that the spelled speech code is well suited as an auditory output for the Lexiphone. The intelligibility score is much better when the user is allowed to vary the presentation speed and rescan the missing words.

WORD LENGTH AND INTELLIGIBILITY

In this spelled speech experiment, many errors occurred with long words. A calculation was hence made on the number of errors observed at different word lengths. The result is shown in Table 10.

It can be seen that the longer the word, the more likely an error will be made. This is true even when a longer pause was given for decoding a longer word. In some cases, the subjects reported insufficient time for the perception of long words. In other cases, they forgot some of the letters especially those which occurred at the beginning or in the middle of long words. These can be

wpm	45	55	65	75
45	--	**	**	**
55		--	**	**
65			--	**
75				--

kHz	5	6	4	3
5	-			**
6		-		*
4			-	
3				-

** $p < 0.01$ * $p < 0.05$

TABLE 10

Overall Percent Correctness of Words According to Word Length

Word Length (No. of Letters)	4 or less	5	6	7	8
Percent correctness	92.13	83.58	80.21	76.84	62.50

attributed to two factors. First, since long words occur less frequently in the English language, they were less familiar to the subjects. Second, some subjects perceived long words letter by letter, some of which they forgot as the word length exceeded their immediate memory span. The latter factor became less important as the subjects became more skillful in decoding spelled speech. It is expected that through practice, they will eventually perceive chunks of letters in the form of syllables or words, rather than one letter at a time.

TESTS ON THE SPELLEX TALKING TYPEWRITER

The applicability of the spelled speech code to the Spellex talking typewriter was tested using several groups of blind students from a school for the blind. A block diagram of the computer-simulated Spellex typewriter is shown in Fig. 1. It gives the typist an auditory feedback each time a key is depressed. For example, on pressing the letter "a," the typist hears the voice say "a." In order to improve the performance, an editor which enables a blind typist to eliminate typing errors has been added to the Spellex system. A block diagram is shown in Fig. 2. It operates in four modes of operation, "type," "search," "output," and "command." In the type mode, the typist can type in the text or a command string for mode changes. The search mode allows the operator to locate the position of a word or a letter for insertion, deletion and other corrections. The output mode commands the typewriter to print the corrected version of the typescript.

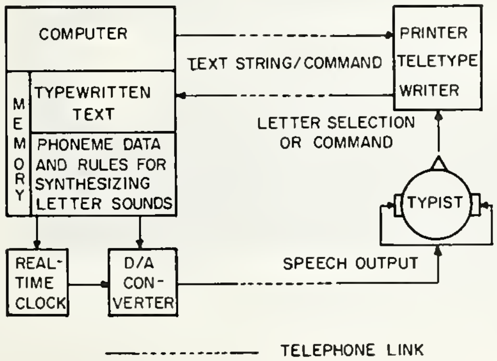

Figure 1. Network of the Spellex Automatic Talking Typewriter

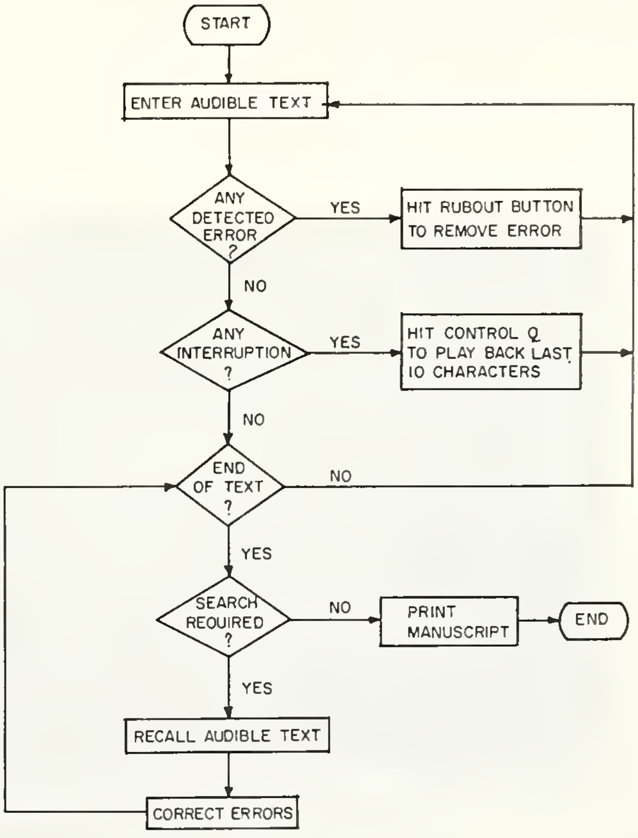

Figure 2. Operation of Spellex

The command mode gives the typist full control over the selection of operating modes.

Several Spellex networks have been installed in Vancouver and Montreal and we have been encouraged by blind typists' success with this machine (Beddoes and Suen, 1973). It has been found that using the Spellex typewriter improved the typing accuracy. For a group of more advanced typists, both the accuracy and the typing speed improved providing further evidence that the spelled speech code is a useful aid for blind typists.

DISCUSSION

A series of experiments have been conducted to test the feasibility of using a synthesized spelled speech code as an output for both the Lexiphone reading machine and the Spellex talking typewriter. The results indicate that spelled speech is easy to master and it provides a useful communication link between the blind and machines.

The encouraging experimental results have led us to design and build a digital spelled speech generator for use with the Lexiphone reading machine and the Spellex talking typewriter in place of the computer. This would make both speech aids economically feasible. We have finished building the first prototype spelled speech generator and a picture of the unit is shown in Fig. 3. Presently we are exploring the applications of the spelled speech unit to other instruments and we shall report our progress in the future.

ACKNOWLEDGEMENT

This research was supported by grants from the National Research Council and the Medical Research Council of Canada, the Vancouver Foundation, the Mr. and Mrs. P. A. Woodwards Foundation and the B. C. Telephone Company. Ching Y. Suen also wishes to acknowledge the financial support from the Ministry of Education of Quebec.

Figure 3. A Prototype Spelled Speech Generator and the Talking Typewriter

REFERENCES

1. Beddoes, M. P. Possible uses of a printed braille reader with spelled speech output, Proc. of the International Congress on Technology, The American Foundation for the Blind, 1963, pp. 325-42.

2. Beddoes, M. P. & Suen, C. Y. Experimental study of the Spellex editing talking typewriter. Proceedings of the International Conference on Cybernetics and Society, Boston, November 1973.

3. IEEE, 1965 revised list of phonetically balanced sentences (Harvard sentences). IEEE Trans. Audio and Electro-acoustics, 17, 239-246, 1969.

4. Metfessel, M., & Lovell, C. Spelled speech as output for an automatic reader. Research Report, Psychology Department, University of Southern California, Los Angeles, 1961.

5. Metfessel, M. Experimental studies of human factors in perception and learning of spelled speech. Proc. of the International Congress on Technology, The American Foundation for the Blind, 1963, pp. 305-08.

6. Metfessel, M., & Lovell, C. Guidelines for developing an alphabet to synthesize spelled speech. *Bulletin of Prosthetics Research*, Veterans Administration, U.S.A., Spring 1972, pp. 154-76. (This is the most complete account of Metfessel-Lovell's work.)

7. Suen, C. Y. & Beddoes, M. P. Dichotic presentation and time compression of the spelled speech language. Paper presented at the Fourth Annual Audio-Tutorial Congress Conference, Columbia, South Carolina, November 2-4, 1972.

8. Suen, C. Y. Computer simulation, development and evaluation of a high speed spelled speech code. Ph.D. Thesis, Department of Electrical Engineering, University of British Columbia, Vancouver, June 8, 1972.

9. Suen, C. Y. & Beddoes, M. P. Development of a digital spelled speech reading machine for the blind. IEEE Trans. on Biomedical Engineering, Vol. BME-20, 452-459, November 1973.

10. Winer, B. J. *Statistical Principles in Experimental Design*. New York: McGraw-Hill, 1962, 575-577.

11. Beddoes, M. P., Suen, C. Y., Dixon, B. A., & George, R. C. Spellex: An automatic talking typewriter for the blind. 10th International Conference on Medical and Biological Engineering, Paper 38.11, Dresden, August 1973.

APPENDIX

Plan of Spelled Speech Experiment with 16 Blind Subjects

		L_1	L_2	L_3	L_4
I_1	G_1	a_3b_3	a_4b_1	a_1b_4	a_2b_2
	G_2	a_1b_2	a_2b_4	a_3b_1	a_4b_3
	G_3	a_2b_1	a_1b_3	a_4b_2	a_3b_4
	G_4	a_4b_4	a_3b_2	a_2b_3	a_1b_1
I_2	G_5	a_3b_3	a_4b_1	a_1b_4	a_2b_2
	G_6	a_1b_2	a_2b_4	a_3b_1	a_4b_3
	G_7	a_2b_1	a_1b_3	a_4b_2	a_3b_4
	G_8	a_4b_4	a_3b_2	a_2b_3	a_1b_1

I: Interval of pause between words.

I_1 = fixed interval = 4.4 T_L

I_2 = interval increases linearly with word length = $m\ L_W + 2\ T_L$

where T_L = pause between letters

L_W = word length

and $m = 2.4\ T_L/4.4 = 0.545\ T_L$.

G: Subject group, there were two subjects per group.

L: List of testing materials, lists 13, 16, 22, and 45 of PB sentences were used.

a: Speed of presentation, four speeds were used, viz. 45, 55, 65, and 75 wpm.

b. Bandwidth of letter sounds, four bandwidths were used: 3, 4, 5, and 6 kHz.

OBSTACLE DETECTION WITH AND WITHOUT THE AID OF A DIRECTIONAL NOISE GENERATOR

N. V. Clarke, G. F. Pick, and J. P. Wilson*

Abstract: The nature of obstacle detection by *facial vision* is discussed and the main underlying clues are identified as acoustic images and reflection tones. A directional sonic torch was developed to enhance these natural clues. Static experiments and an obstacle course were devised to assess performance in four groups of subjects. The long-time blind adults and children showed many more unaided static detections than the newly blind or blindfolded sighted subjects. With the aid, many more detections were made by all groups which then showed similar performances. On the obstacle course the blind children and blindfolded subjects detected most obstacles and the newly blind subjects least, but the blindfolded subjects were much slower in completing the course. Use of the aid approximately doubled both the number of detections and the distance at which detection occurred. Aided and unaided detection improved throughout the tests.

INTRODUCTION

The general aim of the investigation reported here was to obtain some quantitative measures of sonic obstacle detection with and without the aid of a directional sonic "torch," and to ascertain whether practice with a device of this type, which essentially enhances the natural clues used unconsciously by skilled blind people, could lead to improvements in unaided performance.

It has been known for a long time that blind people can sense an obstacle at a distance and move around it without needing to touch it. The physical basis for this ability, however, has only recently become well understood. The reason for this would appear to be that the subjective impressions elicited by the proximity of an obstacle bear little relationship to the physical stimuli involved. Kohler (1952, 1967), who was particularly interested in the basis of these subjective impressions, has reported descriptions such as being "similar to a slight touch or pressure," "a kind of tactile sensation somewhere near the eyes," and "like bumping into a spider's web, only much lighter"; blindfolded-sighted subjects and the recently blind spoke of "darkening before the eyes." The nature of these impressions has given rise to the term *facial vision*. However, Dallenbach and coworkers demonstrated convincingly that the basis is auditory and not tactile. Earlier workers had apprently even entertained the possibility of some "sixth-sense" being involved. It is necessary to understand the basis of obstacle detection if a device is going to make optimal use of these natural abilities.

The Obstacle Sense

Supa, Cotzin, and Dallenbach (1944) provided a survey of the early studies and presented their own series of experimental investigations. They showed that blind and blindfolded subjects were poor at detecting obstacles

*University of Keele, Department of Communication, Staffordshire, England.

when walking without shoes on a carpeted floor, and were unable to detect obstacles at all with their ears blocked or masked by sound. On the other hand they showed that covering the exposed skin areas with felt, allegedly to cut out any "pressure" clues, made no difference except that which could be attributed to the slight acoustic absorption. More importantly they demonstrated that subjects in another room could detect obstacles over headphones, even monaurally, when the experimenter carried the microphone towards the obstacle. Worchel and Dallenbach (1947) showed that deaf-blind subjects were not able to anticipate obstacles. Thus it appears that audition is necessary and sufficient for obstacle detection, although there may occasionally be special conditions where other clues such as wind patterns, odors, heat radiation, etc. could be of some use.

Cotzin and Dallenbach (1950) investigated which frequency region was most important by using pure tones and a similar microphone and headphone arrangement. Continuous pure tones between 125 Hz and 2 kHz yielded few detections with an increasing number for frequencies from 2 to 10 kHz. It would appear from the descriptions of the subjects that they were making use of the increasing peak-to-valley ratio in the standing-wave patterns as the loudspeaker and microphone approached the obstacle, although Cotzin and Dallenbach suggested that the clue was an increase of pitch which they attributed to the Doppler effect. Subjects found detections far easier when white noise was used as signal, and reported a distinct increase in pitch. Twersky (1951) investigated the detection of obstacles with the aid of a directional high-frequency tone generator. Although he reported that an interrupted tone yielded better detection (see below), it appears that in the majority of his experiments he used a continuous tone. He stated that obstacles were detected by means of the increasing intensity of the echo, together with an increase in pitch which he thought resulted from this increased intensity (see Stevens [1935] but also below). Ammons, Worchel, and Dallenbach (1953) carried out experiments on the detection of obstacles with the aid of various self-generated noises such as footsteps. The performance of the blindfolded (sighted) subjects was slightly worse under some outdoor conditions than indoors. This worsening was attributed to the higher ambient-noise level, and wind noise.

Apparently inspired by the impressive echolocating abilities of bats and porpoises, and also the technical capabilities of sonar and radar, Kellogg (1962) undertook an investigation of what he called the "sonar system of the blind." He measured the just detectable change in the distance of a small disc from the face of the subject. The subjects were instructed to make their judgments with the aid of vocalizations. They noticed during these experiments that the most effective vocalizations contained a number of sibilant and/or stop phonemes. Generally, in previous experiments little difference had been found between the echolocating performance of blind subjects and blindfolded subjects who had had a minimal period of training. In this experiment, however, the trained blindfolded subjects were almost incapable of estimating relative distance, while the blind subjects could detect differences in distance of between 10 to 20 cms at 60 cm for a 30-cm diameter disc. He also reported that subjects showed some ability to discriminate between hard and soft textures. Rice, Feinstein, and Schusterman (1965), and Rice (1967) continued with the study of size and distance factors in echo detection. Blind subjects were required to detect discs of different sizes at a variety of distances again using vocalizations. It was found that each disc subtended an angle of approximately 5° at the distance at which 50 percent detections were obtained.

Next, Rice generated artificial hisses (continuous white noise) and clicks (pulse trains) using a fairly directional loudspeaker placed in front of the subject's mouth. None of the artificial or oral signals was found to be consistently better than the others. After training, some of the subjects were able to discriminate slightly between circular, square, and triangular surfaces at distances of less than 90 cm using vocalizations. Rice also noted that, in general, detection was as good monaurally

as binaurally, but that a mild hearing loss generally led to some deterioration of detection ability.

Although there have been observations of a "pitch" effect, or "reflection tone," in the neighborhood of broadband sources of noise such as waterfalls predating Dallenbach's reports by a century, and the physical principles involved have been understood for a similar period, this phenomenon does not appear to have been specifically related to obstacle detection by the blind until the report of Bassett and Eastmond (1964). They showed that *interference* between direct sound from a white noise source and that reflected from a surface gave a series of *spectral maxima* at multiples of the frequency, $c/2d$, where, c, is the velocity of sound and, d, the distance of the microphone or observer from the reflecting surface. This arises because the time delay between the direct and reflected sound is $2d/c$. Approaching the surface shortens the delay and gives more widely spaced spectral maxima with a higher pitched sensation. There has been considerable interest in the auditory mechanism underlying this pitch sensation which Bassett and Eastmond incorrectly attributed to difference tones due to intermodulation distortion within the ear (Fourcin, 1965; Wilson, 1967, 1974; Bilsen, 1968). It also appears to be related to the "sweep-pitch" effects produced by pulse pairs (Thurlow and Small, 1955). This signal has the same power spectrum as noise plus delayed noise and of course is relevant to echolocation when impulsive noises such as footsteps, hand clapping, or tongue clicks are utilized. No pitch modification can, of course, arise in this way for a pure-tone signal. Thus it would appear likely that the slight pitch effects with tones noted by Cotzin and Dallenbach, and Twersky could have been due to residual noise in the signal or spectral spread due to gating the tone. Wilson (1967) showed that the extreme limits of obstacle detection via the reflection tone would be 1 cm to 5 cm.

The reflector may also modify the spectrum of the signal in other ways. Small or medium sized obstacles will reflect a greater proportion of high, rather than low frequencies. It would appear, however, from the results of Experiment III below that this cannot be a particularly influential factor although it may be the basis of the shape discrimination reported by Rice. The obstacle may also selectively absorb and reflect certain frequencies, and because of its construction exhibit resonances and antiresonances at certain frequencies. A galvanized iron pipe in the present study could quite easily be discriminated from a plastic one of the same geometry because of the "tinny" timbre of its reflection. It is not known whether subjects are able to use spectral information caused by different surface textures but this would appear to be of secondary importance.

In addition to the various *spectral* clues which will be available whenever broadband ambient or impulsive sounds are present there are *temporal* clues such as separately perceived echoes when the delay is long enough and *spatial* clues such as *acoustic images* for both short and long delays. Although acoustic images like optical images should be situated as far behind a plane-reflecting surface as the source is in front; in practice they sound to originate from the surface itself. Presumably this is because the rate of change of intensity at the ear produced by observer and source moving up towards the obstacle would be the same as that for a stationary source at the surface. For an acoustic image to be perceived it is necessary that the ears should be able to resolve source and image spatially, and that the Haas or precedence effect, in which sound appears to originate from the direction of the earlier of two sound sources (see Gardner, 1968) should not predominate. The latter effect may be a contributory factor towards localizing the acoustic image at, rather than behind, the reflecting surface. The range of greatest practical interest to the blind person is that in his immediate neighborhood where echoes are not separately perceived. Thus two clues, *reflection tones* and *acoustic images*, stand out as being chiefly responsible for obstacle detection. In general, geometrical arrangements of source, reflector, and observer which favor one of these clues tend to obscure the other. In an ingenious experiment

that introduced both of these clues (though not separately controlled) Kohler (1967) was able to elicit the sensation of facial vision. Subjects were initially required to detect obstacles with the aid of a small-sound source. Kohler found that if instead of a real obstacle he moved up a second sound source relaying the same sound they detected it as if it were a real obstacle and obtained similar subjective impressions. He was able to show in other experiments that anaesthetising the skin had no effect on these sensations.

It would appear plausible that tactile sensations arise centrally by a process of association or conditioning. Bumping into an object results in strong tactile sensations and therefore detecting or sensing an object by some unidentified means might be expected to lead to a minified and perhaps graded tactile sensation, akin to pressure on the face, which increases as the object is approached.

Now that the basic clues for obstacle detection have been identified it is possible to consider both the limitations and how detection might be optimized. For either clue it is necessary that the obstacle should reflect sound into the ear of the observer. The obstacle has to be sufficiently large compared with the wavelength of sound and appropriately orientated for reflection (i.e., for the acoustic image to be "visible" in its surface). For small objects of a few centimeters in diameter, only the highest audible frequencies will be reflected and to detect wires it is necessary to use ultrasonic frequencies. Although, in theory, it should not be possible to detect an external corner with self-generated or carried-sound sources, because the sound will be reflected away from the observer, in practice it is frequently possible due to ambient noises from other directions or indirect reflections of the source.

The conditions which favor detection of reflection tones tend to be complementary to those for acoustic images. The former requires shorter delay times, approximate equality between direct and reflected sound levels, preferably continuous noise, and arrival of the sound from approximately the same direction as the source, that is, at the same ear, although the sound source need not be directional. Acoustic images are better detected with longer delays, the minimum possible direct sound from the source, preferably gated noise or pulses, clear directional separation between source and image, and a fairly directional sound source. The directionality required is something of a compromise: a highly directional source gives a very long range and good spatial resolution when scanned but increases the chance of missing a nearby small object because the chance of scanning it is lower. A directional source also contributes to a reduced direct-sound path when pointed at the obstacle, favoring acoustic image perception.

Previous Sonic Mobility Aids

The discovery that humans can echo-locate well in certain circumstances, albeit poorly in comparison to the ability of bats and dolphins, has prompted many people to devise methods of helping blind people to make greater use of this ability. Some of these aids have emulated bats to the extent of using ultrasonic signals, although of course the "display" must be transposed into the audible range (Kay, 1963, 1966; and Beurle, 1972).

It is reported that Kohler used a mechanical clicker (of the type used in a child's toy, a "cricket") in order to demonstrate the detection of echoes. Griffin, in 1943, elaborated upon this theme by placing the mechanical clicker at the focus of a parabolic reflector (see Griffin, 1960). This made the device more directional, giving better resolution of obstacles. However, it would seem that neither of these devices received serious evaluation as aids for the blind. The 10-kHz continuous tone "flash-sound" of Twersky reported above was evaluated by a small group of blindfolded subjects who learned to perceive obstacles far faster with this highly directional aid than with ambient sound alone. Twersky (1953) later went on to develop two further types of echo-location aids. The first was a directional, mechanical clicker, very similar to that described by Griffin, the second being a whistle at the focus of a parabolic reflector,

blown by a finger-operated rubber bulb. Twersky reported that his subjects, including one blind man, preferred the whistle to both the clicker, and the flash-sound. They thought that the clicker did not provide good close-range detection, although it was better than the other devices in the region of 6-15 m from the obstacle. They preferred the whistle over the flash-sound, as it provided a wide repertoire of signals, and it allowed rapid pulsing of the signal. They felt that the whistle was the best device for use at distances of less than 3 m. Beurle (1951a and 1951b) constructed an electronic aid using a piezo-electric transducer situated at the focus of a parabolic reflector, actuated by capacitor discharge. Thus, this was an electronic version of the clicker first used by Griffin. Beurle evaluated the device using a large variety and number of blind subjects. While subjects were initially very enthusiastic, many later reported that the device made little difference in the navigation of familiar routes. Beurle felt that the device would not be of sufficient usefulness to be carried at all times by the blind person, but might find some use as a training device for blind children. Graystone and McLennan (1968) also developed a clicker type of device using a small moving-coil loudspeaker as a transducer, which was evaluated by a group of blind children. It was apparent from the results of their experiments using an obstacle course that the device aided those children with poor navigational ability, but provided no improvement for those already adept at navigation.

Sonic Aid Used in the Present Study

The sound generating device used in the present experiments is shown in Fig. 1. It consisted of two parts: the hand-held "torch" (approximately 24 cms long), containing the sound-source and the associated electronics, connected by a lead to the battery case which was carried on a shoulder strap. The torch weighed approximately 470 g.

The signal used in this study was broadband noise, obtained by amplifying thermal and semiconductor noise. The transducer was an electrostatic loudspeaker element (10 x 12 cm) originally designed for use in a high quality headphone (Wilson, 1968). This has the advantage of producing a plane wavefront for sound wavelengths less than its shortest dimension, giving a directional beam of sound. Larger and smaller diameter radiators were also tried giving narrower and broader distribution patterns respectively. From these tests it appeared that

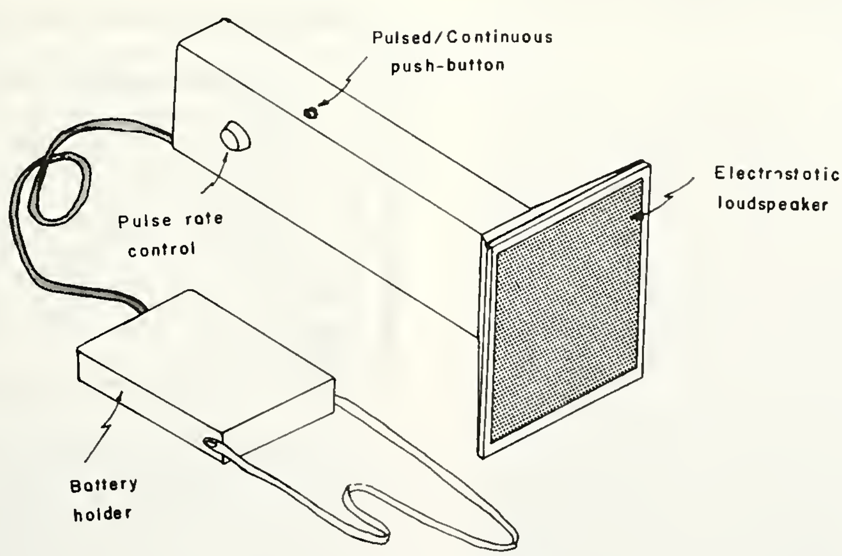

Figure 1. Sound Generating Device

the present radiator, giving a beamwidth with half-energy points separated by 25° over the range 5-20 kHz, would be the best compromise. At a distance of 5 cm from the transducer, on-axis, the energy spectrum of the noise was flat with a sound pressure level of 70 dB in the frequency region 1-20 kHz (±3 dB). The noise was normally gated, at a rate which was continuously variable from about 1 to 20 pulses-per-second. The gating function had an equal mark/space ratio, but could be switched out for continuous noise by pressing a button on the handle.

This facility was incorporated because Twersky's investigations had shown that a click signal was most useful at long range. At short range the echo would return while the noise was still present, while at long range the echo would return during the silent period. Twersky's experiments indicated that the transient signal was useful for ranges in excess of 7 m. Using a gated-noise signal, the echo would occupy the silent gap at a range of 7 m if the gating rate was approximately 14 pulses-per-second. In preliminary experiments it was found that a gating rate between 6 and 10 pulses-per-second provided the optimum compromise between long- and short-range detection. In the majority of the experiments reported the rate was set at 6 pulses-per-second. The ability to switch to a continuous noise was provided, as this gave the clearest reflection tone for short-range detection.

The method of carrying the device had an effect on the ability to detect obstacles. If the device was held too close to the subject's ear the unreflected sound tended to mask the weaker reflections, although as pointed out above, the strongest reflection tones are obtained if the direct and reflected signals have equal intensities. In an earlier prototype there was no rear cover on the generator. Such an arrangement gave a figure eight distribution pattern with no radiation to the ears when held by the side, and also gave a clear reflection tone when held at arms length. However the back radiation proved to be confusing at other positions and during scanning and was eliminated. In the present form, holding the device at hip level proved to be most advantageous. When held at this level a large object at 1 m distance returned a first reflection which is approximately 6 dB above the level of the direct plus multiple-reflected sound at the subject's ear (the difference can be as great as 16 dB in anechoic surroundings).

A simple alternating vertical and horizontal scanning procedure was evolved covering that part of the environment which was in the direct path of the subject.

Preliminary trials indicated that the prototype device did not perform as well outdoors as indoors, partly because wind could interfere with the operation of the transducer. Also, because the much higher levels of ambient noise frequently found outside impair detection as found by Ammons et al. (1953).

EXPERIMENTS

The aim of the experiments was to evaluate the device as a training aid for echolocation and as an everyday mobility aid.

TABLE 1

Obstacles

Shape	Dimension	Surface Material
Plane board	180 cm high 90 cm wide 120 cm high 30 cm wide, 15 cm wide	sized hardboard
Cylinders	160 cm high 23cm diam. 140 cm high 7cm diam	galvanised iron polished plastic
Step ups/ Kerbs 	90cm long, l= 20 cm, 13 cm, 5 cm	sized hardboard

Details of the obstacles and the subjects used are shown in Tables 1 and 2 respectively. The only obstacle which subjects found very easy to *identify* was the 23-cm diameter galvanized iron pipe, whose echo had a "tinny" timbre.

TABLE 2

Subjects

Group	Description	Age	No. of * years blind	Where tested
Blind children	2 boys + 2 girls	12–14 yrs	>10	Blind school library
Long-time blind	4 men	middle aged	>10	Blind workshop ' assembly hall + office suite
Short-time blind	4 men	middle aged	1-3	Blind workshop ' + office suite
Blindfolded sighted	4 men 3 authors 1 technician	25–45yrs	0	Keele + ' Blind school library

* No subject was blind from birth

' 1st mentioned venue for experiments I - III

2nd " " " " IV

The obstacles were designed to simulate those found in a normal environment, and in particular street furniture such as telephone poles, bus stop posts, and curbs.

The hearing of all subjects was tested. One of the long-time blind persons showed a considerable hearing loss at frequencies in excess of 4 kHz in both ears. One of the blindfolded subjects showed in both ears a sharp notch of about 40 dB in his audiogram in the region of 4 kHz but only a 10-dB loss for lower and higher frequencies. The results for both of these subjects were examined individually, and they showed a slight, but statistically insignificant, reduction in their ability to detect obstacles by means of echolocation. For the first subject this appeared rather surprising, considering the findings of Rice. Experiments were carried out serially in the order given, and required about two months to complete the series. Each subject was tested during two 40-minute sessions each week. The experiments were carried out in ordinary rooms of medium reverberation, although, as may be seen in Table 2 subjects were not all tested at the same location.

Experiment 1 --
Static discrimination

The object of this experiment was to determine the range of detection for different obstacles by measuring how frequently they could be detected at different distances; both by using the aid, and by means of ambient noise alone.

Method

In a preliminary experiment, the subject was placed near the center of the experimental room and asked to rotate on the spot with the aid pointing directly in front of him. He was asked to report any echoes that he perceived. These echoes were, of course, excited by walls and fixtures within the room. Steps were taken to reduce them, either with the aid of curtaining, or with auxiliary reflectors. In this way, the more prominent of the room-excited echoes were eliminated. The direction of any remaining echoes was then noted. These directions were never used for the siting of obstacles to be detected, and any detections made in those directions were ascribed to room reflections. There then followed a short training period in which subjects were requested to report the moment at which an obstacle was silently placed before them. The aim of this training was to reduce the number of false detections made and the results indicated that in the majority of cases this was achieved.

Main experiment procedure. While the subject was outside the experimental room, the experimenter arrayed a random selection of one, two, or three obstacles (including the possibility of two similar obstacles) at randomly selected distances (in multiples of 60 cm), and at randomly selected directions around the point at which the subject was to stand. The front surfaces of boards and kerbs were placed in normal fashion to the subject. Occasional trials were interspersed in which no obstacle was present. Trials with and without the aid were interspersed (approximately two trials with the aid to one without). On trials without the aid, subjects were encouraged to make any noise they felt would be helpful. Subjects were tested on six occasions with each obstacle at each of the distances. Once the obstacles had been placed, the subject was brought to the test point by a circuitous route, and

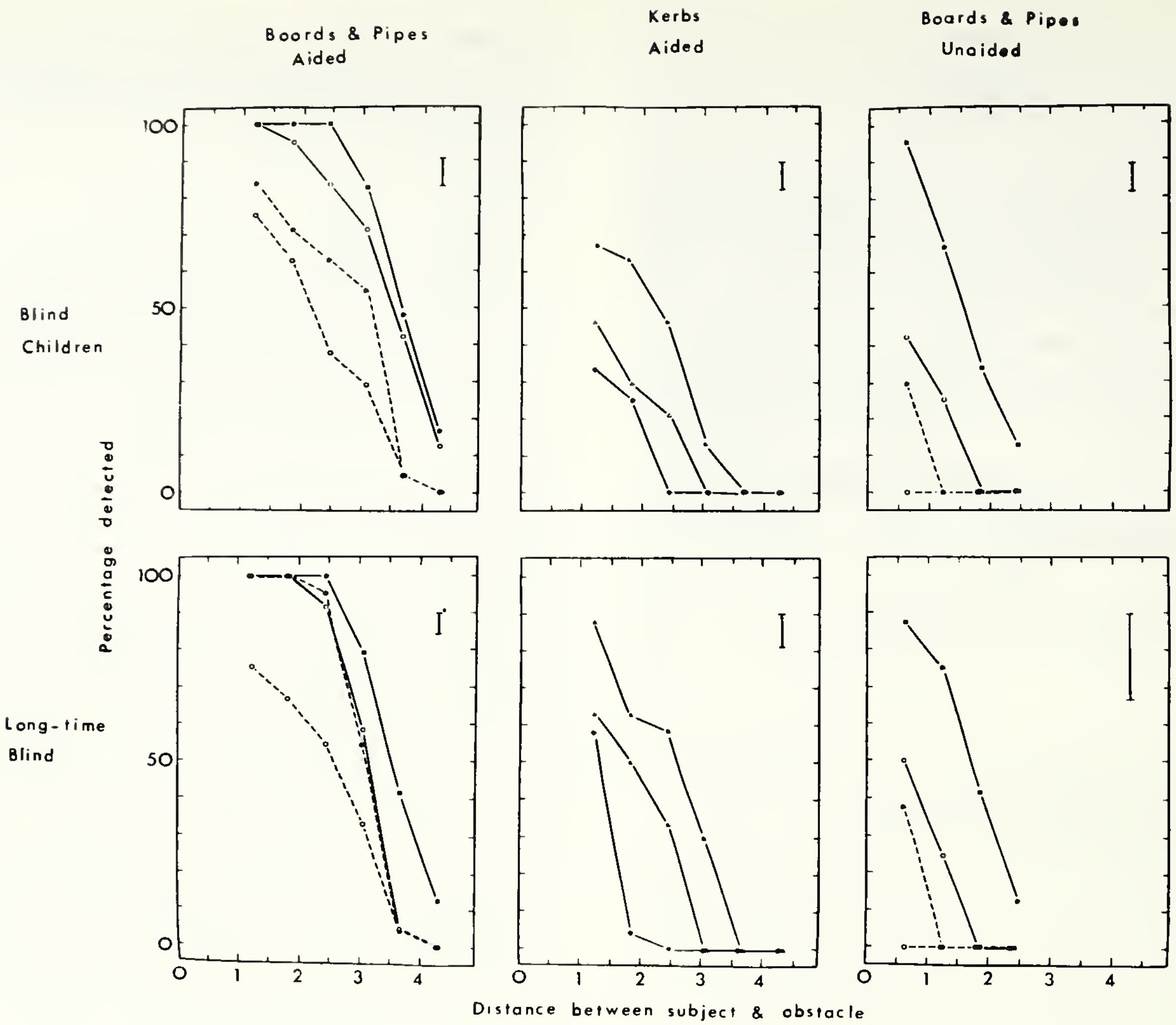

Figure 2a. Percentage of Obstacles Detected as a Function of Obstacle Distance Parameter: Obstacle Type; ■ —— ■ 30-cm wide board; □ —— □ 15-cm wide board; ● --- ● 23-cm diameter pipe; o --- o 7-cm pipe; ▲ --- ▲ 20-cm kerb; △ --- △ 13-cm kerb; ◆ --- ◆ 5-cm kerb. The bars indicate mean standard error.

rotated on the spot in order to disorientate him. He was instructed to rotate on the spot and report any obstacles that he detected. The experimenter, wearing soft soled shoes, stood behind the subject, and noted detections as they were made, during one revolution of the subject. It is interesting to note that the experimenter often heard echoes which the subject missed. When a subject had made a detection, he was asked to stop and point towards it. Although it was found that the ability to point precisely at an obstacle is poor in some blind people, the experimenter could usually ascertain that the subject was perceiving the relevant reflection by hearing its echo himself.

Results

The percentage of detections for each obstacle, at each distance, was calculated, and is plotted as the mean over each group of subjects in Figs. 2a and 2b. As might be expected, those obstacles which reflected the most sound, due to their dimensions and

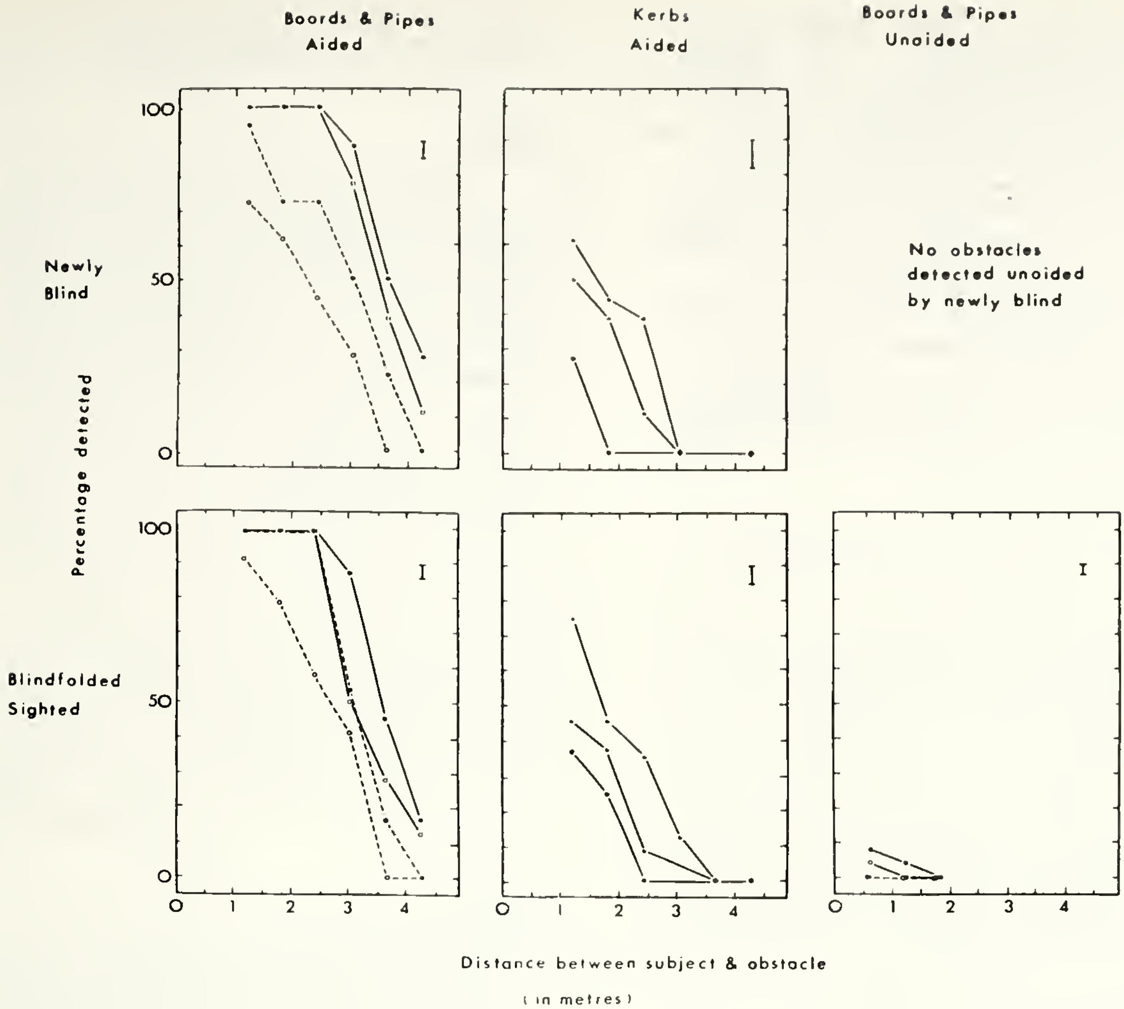

Figure 2b. Percentage of Obstacles Detected as a Function of Obstacle Distance

orientation, were detected most easily, the 30-cm wide board being detected on the greatest percentage of trials, and the 5-cm high kerb the least. The hypothesis that the subjects when using the aid, were members of the same statistical population was not disconfirmed at the 5-percent level of significance. Similarly, the hypothesis that each of the groups were from the same population was not disconfirmed at this level. However, without the aid the groups fell into two populations: the newly blind plus the blindfolded, who detected very few obstacles unaided, and the blind children plus the long-time blind, who did rather better. No subject detected a kerb unaided. The most distinctive difference between the two groups of subjects is that one had much less experience of blindness than the other. Hence, it might be postulated that those who had been blind for some time had developed the ability to detect obstacles by means of ambient sound. This skill apparently takes some time to develop when no explicit training is provided, as the newly blind (blind from 1 to 3 years) had not yet acquired it. It is interesting to note that those unskilled in unaided echolocation, performed just as well as the other groups when using the aid.

If one assumes that the limiting factor for perception of the boards is their width, then it is clear, especially when the aid is used, that a given percentage detection is not achieved for the same angle of

subtense when differing widths and distances are employed. This appears to be contrary to the results of Rice, Feinstein, and Schusterman (1965). The reason for this might well be that the obstacles used in the present study are somehwat larger than those used by Rice et al., and are easily detected at a greater distance. Above a certain size a further increment would not be helpful except for very low-frequency sound. At distances at which detection becomes uncertain, perhaps the limitation is imposed by factors other than the just perceptible audible angle, that is by the reflection being masked by ambient and unreflected noise.

There is some indication that the detectability of kerbs may be greatest in the region of 1 m. This observation prompted a subsidiary experiment using the 13-cm high kerb, which showed, for a single subject, that detection was considerably worse at a distance of 0.2 m than at a distance of 1 m. This is presumably because the corner between the vertical face of the kerb and the floor reflects less energy when the subject is close to the obstacle, than when he is at some distance. More information will be given on this point in the report of Experiment IV.

Experiment II--Maximum Angular Displacement

It is apparent that a plane obstacle which is detected with the aid of *specular reflection* may not be detected if it is displaced by even a small angle from the perpendicular to the listener. The exact angle at which detection is lost depends upon the geometry of the reflector and the relative positions of the sound source, and the listener's ears. However, specular reflection is not the only means whereby sound could reach the listener. The angle at which the plane may be turned may be increased because the obstacle is to some extent a diffuse reflector of sound, or because diffraction has led to sidelobes of sound being produced at the edge of the plane. Hence, it was of some interest to investigate the maximum angle of tilt for some of the plane boards used in the present study. The ability to detect at relatively large angles could be of interest for a blind person in detecting, for example, partially open doors.

Method

The maximum angle of tilt was measured for the 90-cm and 30-cm wide boards at distances of 1.2, 1.8, and 3.6 m. The board was placed at the given distance in front of subject, standing at the center of the room, and perpendicular to the line between the center of the board and the subject. A 360° protractor was placed beneath the center of the board, and the board was slowly rotated about this vertical axis until the subject reported that he could no longer detect the board. The angle was noted. The board was then slowly rotated back as the subject continuously scanned across the target area, until the subject once again reported detection. The mean of these two angles was taken as the threshold. Each board and distance was selected at random for measurement. The threshold for each subject at each distance was the mean of six such measurements.

Results

The resulting threshold is shown in Fig. 3. This figure shows the results averaged over all subjects, as the χ^2-test showed no significant difference between the results for the four groups (at the 5-percent level of significance). The results are rather disappointing for these two obstacles, as even at a distance of 1 m the 90-cm board became undetectable when turned through an angle of 20°. Calculation of the just perceptible angle expected from specular reflection indicate that the empirical threshold is somewhat in excess of that calculated (ranging from about 10 percent at the shortest distance to about 80 percent at the longest). Hence, it would seem that non-specular reflection does play a role in the detection. This inability to detect angled surface would seem to be a limitation of acoustic obstacle detection, including ultrasonic frequencies.

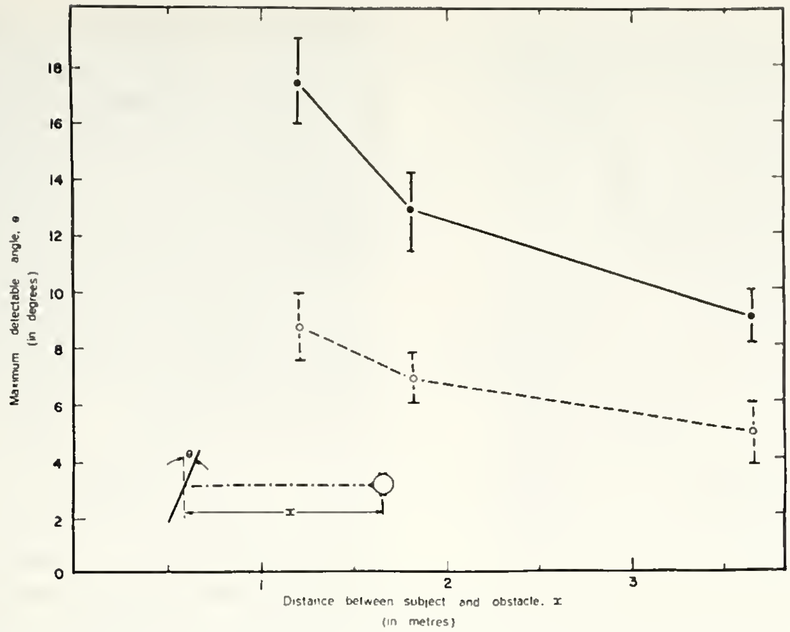

Figure 3. Maximum Angle at Which Obstacle Could Be Detected as a Function of Distance. Inset indicates experimental set-up. Upper curve: 90-cm board; lower curve 30-cm board. Bars indicate the standard error about the mean.

Experiment III--Relative Distances

The aim of this experiment was to determine how well the different groups of subjects could determine the relative distances of various obstacles, the size of which they did not know. With perception of acoustic images it is possible that simply the strength and direction of an echo is perceived so that obstacles at different distances having different sizes, geometries, and surface textures may be indistinguishable. If, however, reflection tones are being used effectively, distance judgments should be correct and uninfluenced by obstacle size.

Method

Two obstacles were placed at about 15° on either side of the subject's midline and perpendicular to him (while he was absent). The left-hand obstacle was placed at one of three distances: 1.2, 1.8, and 2.4 m. The right-hand obstacle was placed at an equal or greater distance than the left-hand one. The obstacles to be compared were: 1.) two 30-cm boards, 2.) two 15-cm boards, 3.) a 30-cm and a 15-cm board, or 4.) a 23-cm pipe and a 7-cm pipe. The comparison of obstacles was carried out in the order given above, but all other variables were randomized. Subjects were not told which obstacles were being used or at what distances. Each subject made each comparison on six separate trials. The task of the subject was to report whether the right-hand obstacle appeared further, equidistant, or nearer. A "right, further" response was scored +1, "same distance" as 0, and "left, further" as -1. Although, unfortunately, the design of this experiment was faulty in that the right object was never nearer, and subjects were allowed to respond "same," it appears that subjects were not greatly influenced by these shortcomings and the results are worthy of comment.

Results

The mean score for all of the subjects is presented in Fig. 4. The ordinate corresponds to the proportion of "right, further" responses. Once again there was no significant difference between the different groups. This is contrary to the results of Kellogg (1962) who had shown that experienced echolocators could make fairly accurate serial discriminations of whether an obstacle had been

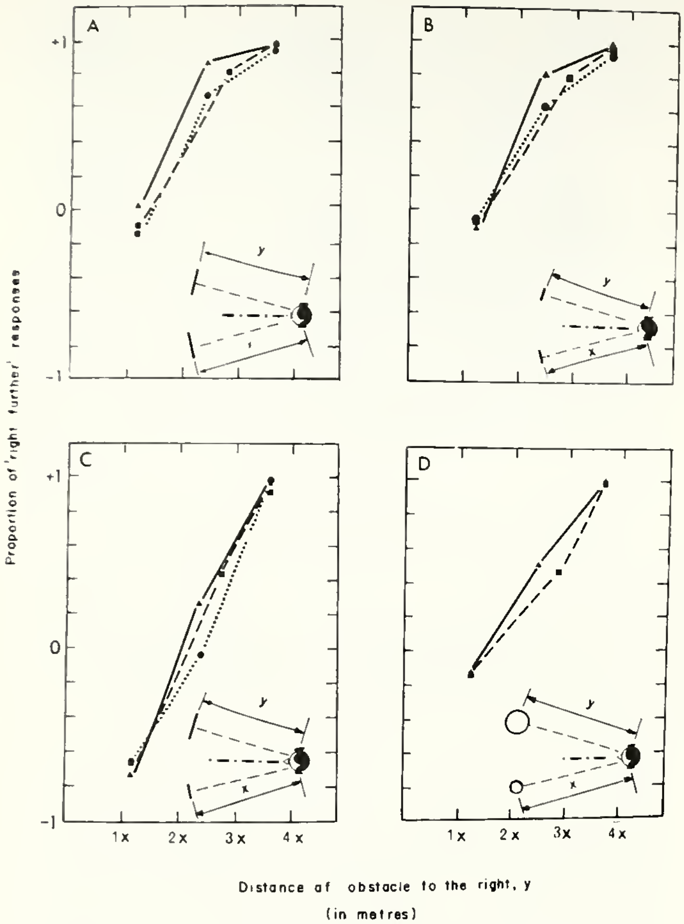

Figure 4. Relative Distance Judgments for a Pair of Obstacles. The left-hand obstacle was set at one of three randomly selected distances, 1.2 m, 1.8 m, or 2.4 m, while the right-hand obstacle was varied in multiples of this. Inset indicates arrangement for (A) two 30-cm boards, (B) two 15-cm boards, (C) a 15-cm board (left) and a 30-cm board (right), (D) a 7-cm pipe (left) and a 23-cm pipe (right).

moved closer, or further away, while an inexperienced echolocator (blindfolded subject) lacked this ability almost entirely. A result which is common to all of the comparisons tested is that the proportion of judgments: "right, further" as a function of the relative distance of the rightmost obstacle is fairly independent of the absolute distance of the leftmost obstacle. This would seem to be an indicator that the solid angle subtended and therefore perhaps the relative sound intensity might be the clue used to make the judgment of relative distance. When the two obstacles are identical (as in Fig. 4A for two 30-cm boards, and Fig. 4B for two 15-cm boards) then subjects have little difficulty in reporting the true relationship of the obstacles. However, when the 15-cm board is compared with the 30-cm board, subjects almost always report the larger board to be nearer, when in fact, the two boards are at the same distance. The boards are reported to be at the same distance when the larger board is at twice the distance of the smaller. This result would suggest that the distance judgment is related to the solid angle subtended by the obstacle and that under these static conditions reflection tones do not play an important role. This conclusion is, at first sight, contradicted by the result of Fig. 4D. Here the 23-cm diameter pipe is compared with the 7-cm diameter pipe. To a far greater extent than for the two boards of different size, the subjects were capable of reporting the true relation between the distances of the pipes. Two explanations may be suggested for this observation. The first is that the energy reflected radially by a cylinder less than doubles as the diameter of the cylinder is doubled. Thus, the two cylinders might appear more similar than the boards of different size. A simpler explanation is that in previous experiments a few of the subjects had commented upon the "tinny" timbre of the 23-cm diameter galvanized iron pipe, and this might have provided them with a clue as to which obstacles were being tested. It would seem from the results of this experiment that blind people although accurately detecting the presence of an obstacle, do not have a clear idea of its distance if its size is unknown and, therefore, would be unable to build up an accurate mental map from a single "viewpoint."

Experiment IV--Obstacle Course

The obstacle course was devised to evaluate the device in a situation more closely approximating everyday situations. It was also hoped that this might be useful in allowing comparisons with evaluations of other mobility aids. The performance of the subjects was determined when

negotiating the course both with and without the aid. There were two major reasons for this. One was to provide a base-line level for comparison of performance with the device, and the other was to provide a measure of whether experience gained with the aid led to an improvement in performance using unaided echolocation. In studying results presented for this experiment, it should be borne in mind that all subjects had already gained quite considerable experience in using the aid while acting as subjects in Experiments I to III.

Method

In preliminary training subjects were required to walk around the perimeter of the experimental room using the aid, and attempting to maintain a distance of approximately 0.5 m between themselves and the wall without any collisions. The purpose of this was to familiarize the subjects with the practical use of the aid, and with the experimental room which was later to be used for the obstacle course. Once the subject had become reasonably practiced and knew what path he was to follow, he was led out of the room, and obstacles were arrayed around the course. A typical obstacle course layout is shown in Fig. 5. On each trial one of each of the following obstacles was used: a 30-cm board, a 15-cm board, a 23-cm pipe, a 7-cm pipe, a 20-cm kerb, a 13-cm kerb, and a 5-cm kerb. The sequence and placement of the obstacles was randomly selected on each trial from twelve predetermined plans. These plans were designed to avoid very difficult or ambiguous situations, such as where the subject might confuse an obstacle with a wall behind it, or where a difficult obstacle might be confused with an easier object beyond it. In half of the trials the start was as marked in Fig. 5; in the other half the subject went in the opposite direction around the room and started at the point marked

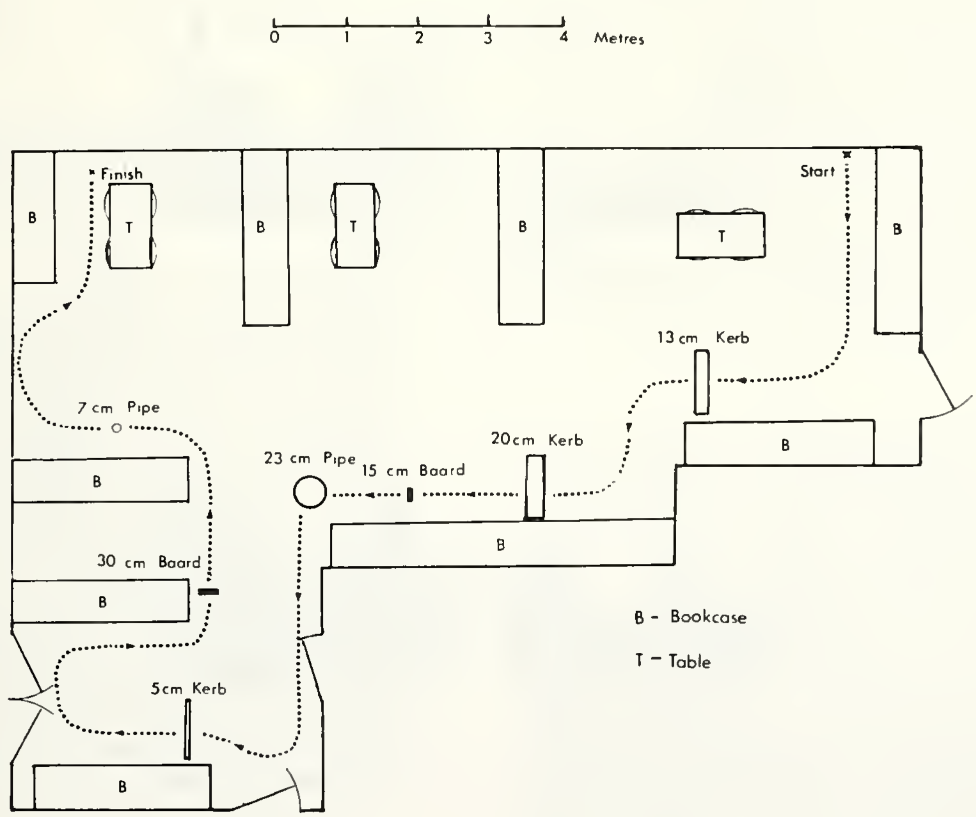

Figure 5. A Typical Obstacle Course Layout.

"finish." Once the course had been set out, the subject was led into the room. He was taken to the start of the course, where he received his instruction. He was required to walk around the room, maintaining a constant distance from the wall. When he detected an obstacle in front of him he was required to stop and report the detection to the experimenter. The experimenter walked quietly behind the subject, and satisfied himself that the subject had indeed detected an obstacle. He then measured the distance between the subject and the obstacle, it was removed, and the subject was asked to continue. In general the time taken between the subject stopping and being requested to continue was between 10 and 20 seconds. Subjects were allowed to collide with the obstacles if they failed to detect them. On collision, the obstacle was caught and removed, and the subject requested to continue. The time taken to complete the course was recorded. Trials with the aid were interspersed with trials without it. The long-time and newly-blind adult groups both performed six trials with, and six without, the aid; the blindfolded, four each, and the blind children; 10 with and six without the aid. Subjects were given instruction in echolocation with the aid, but not without. Subjects adopted various techniques for getting around unaided (e.g., shuffling the feet, sharply bringing down the heel of the shoe onto the floor, jingling coins in the pocket, clapping hands, and clicking fingers and tongue).

Results

The proportion of obstacles detected per subject for each group is shown in Fig. 6. The shaded bars show detections with the aid, and the insert bars those without. The blindfolded subjects performed surprisingly well in this task, both with and without the aid, while the long-time, and newly-blind adults did rather poorly, especially unaided. The blindfolded subjects were, of course, particularly highly motivated and not a matched control group. The blind children performed at about the same level as the blindfolded group. It is not altogether clear why the two groups of blind adults did rather poorly, by comparison, in the obstacle course

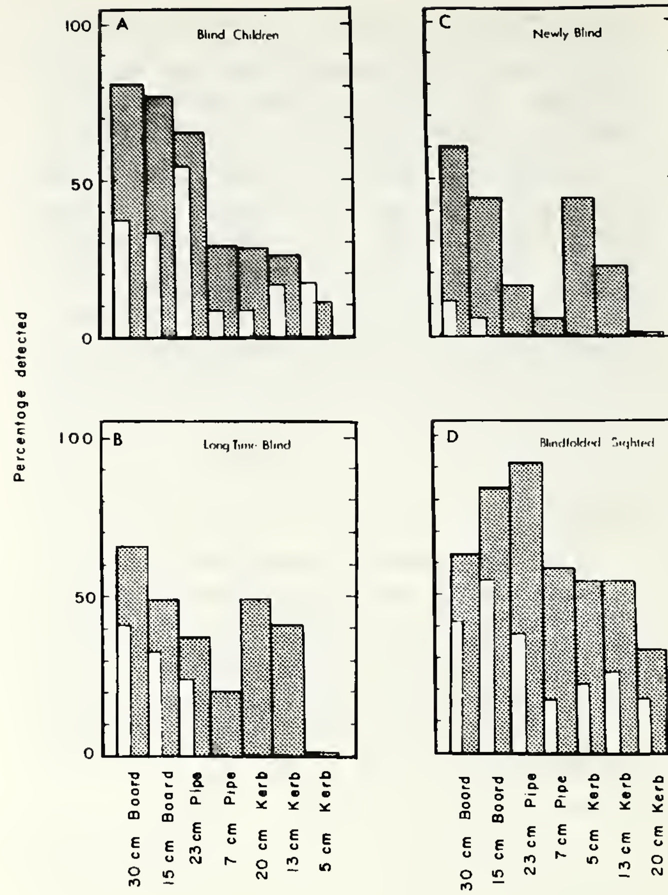

Figure 6. Proportion of Obstacles Detected per Subject for Each Group. Shaded Bars Indicate Detections Made with Aid.

experiment. Although they were less familiar with their experimental course which was also a little more complex, this is not directly relevant to the task of detecting obstacles within it. It appeared, however, that some of the middle-aged blind subjects lost motivation in the rather long series of experiments, and were not as careful as they had been earlier. In support of this, some of them had indicated that they thought it unlikely that an electronic aid would ever replace their present mobility aid (guide-dog in one case, and white stick in the others) and once this indeed proved to be the case, motivation would presumably drop.

In almost every case it is evident that the subjects were able to detect obstacles better with the device than without. The order of

likelihood of detection for the different obstacles was similar to that observed in Experiment I. The blindfolded group had learned to recognize the galvanized iron pipe, and, rather curiously, detected the 15-cm board more frequently than the 30-cm board. The adult blind subjects appeared to have some difficulty in detecting the 7-cm pipe. This might be a result of presbyacusis, as there was some evidence of high-frequency hearing loss in their audiograms. On the other hand, these subjects seemed to show an enhanced ability to detect the kerbs, especially in comparison to the children. This might be associated with the greater difficulty experienced by some of the children in maintaining the prescribed scanning technique. The distance at which the detection was made was measured only for the blind children and the blindfolded adults. The mean distance of detection is shown in Fig. 7, both with and without the aid. It is apparent that detections were made at a far greater distance with the aid than without. This increased distance of detection with the aid would allow the blind person time to take avoiding action while walking at a higher speed. Further weight is added to the suggestion noted in Experiment I, that there was an optimum distance for the detection of the kerbs when using the aid. It seems that if the subject had not detected the kerb at a distance of 0.5 m, then there was little likelihood of him detecting it at all.

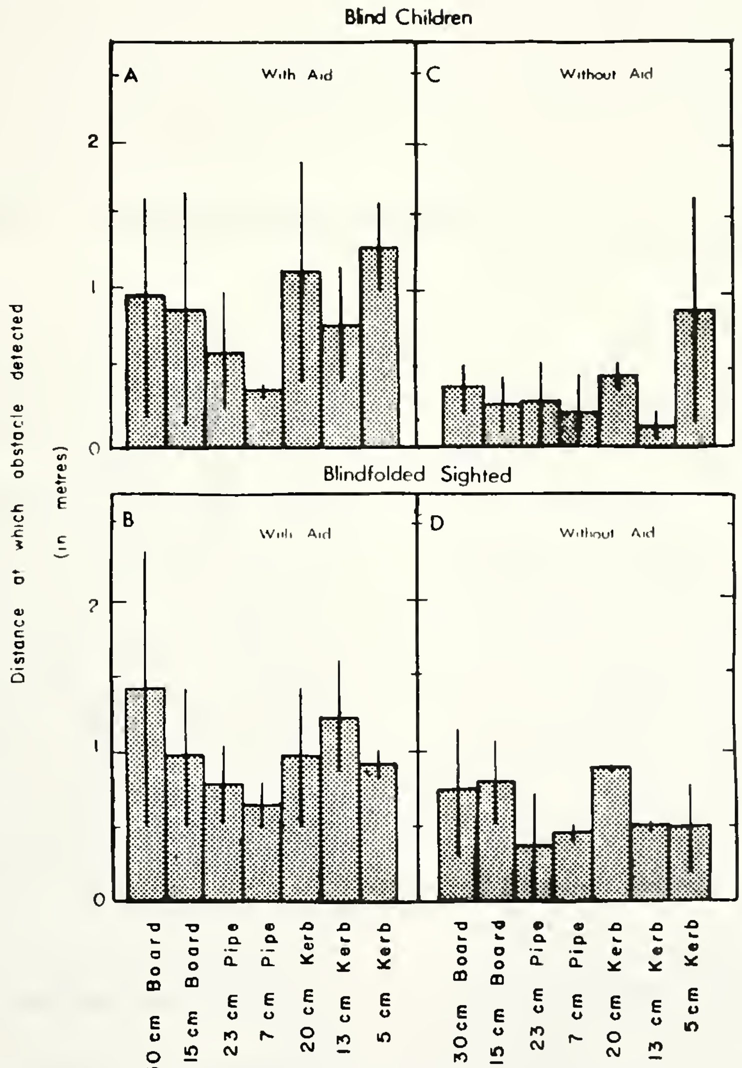

Figure 7. Mean Distance of Detection for Blind Children and Blindfolded Adults With and Without Aid. Bars Indicate Standard Error About the Mean.

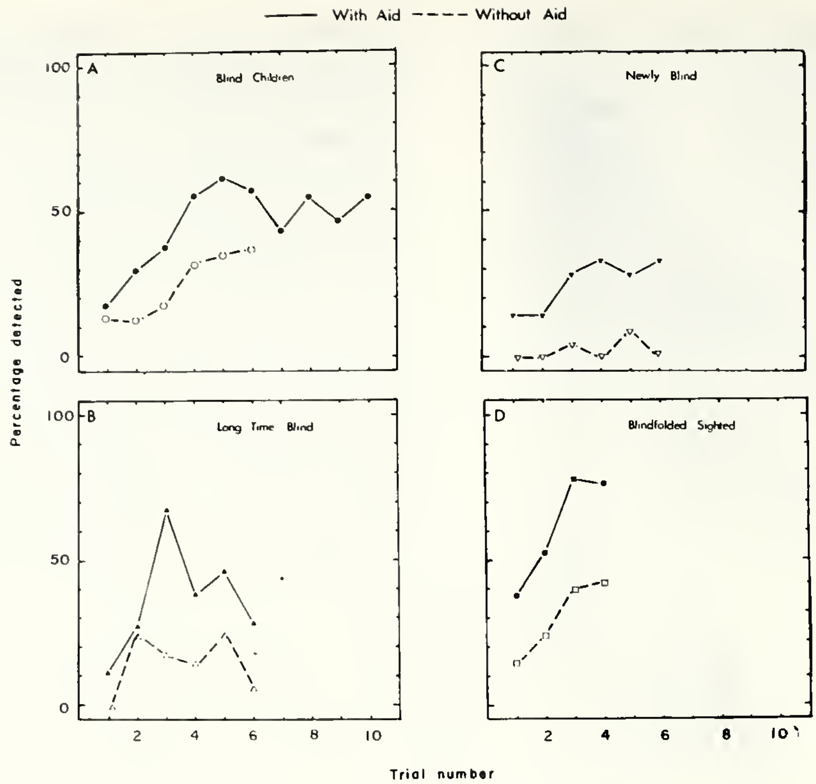

Figure 8. Percentage of Obstacles Detected per Subject as a Function of the Trial Number, With and Without Aid.

Figure 8 shows the percentage of obstacles detected per subject as a function of the trial number. Almost all subjects showed an increase in percentage detection as the trials progressed for both aided and unaided performance, although the performance of the long-term blind eventually declined (see above). None of the subjects had previously received any explicit training in obstacle detection and it is notable that even those blind for a long time could have their unaided performance improved. It is also notable that the blindfolded subjects made very few unaided detections in Experiment I, but by the end of Experiment IV were performing well unaided. The same trend is apparent but less marked for the newly blind group.

The comparatively high level of performance of the blindfolded subjects must be viewed in relation to the mean times to complete the course, (Fig. 9 and Table 3). The blindfolded subjects took considerably longer to complete the course than their blind counterparts, because they were far more cautious and much more concerned about the possibility of colliding with obstacles. They would often stop and scan the environment ahead, before continuing for a few more steps and were thus much less likely to miss an obstacle. It is also noteworthy that subjects took considerably longer to complete the course when using the aid than when without it. This is a similar result to that observed by Beurle (1951b) for blind children navigating in a familiar outdoor environment. A slight contributory factor for the extra time taken to complete the course with the aid was that more detections were made, and so more time was taken in recording and measuring the results. Also, the blindfolded subjects, when deprived of the aid, were less ready to stop and "scan" the environment than when using the aid.

TABLE 3

Mean Time to Complete Course (Min.)

Blind children	with aid	3.5
	without aid	2.2
Blindfolded sighted	with aid	12.0
	without aid	6.0

DISCUSSION

The results of Experiment I indicate that subjects find the aid to be of considerable assistance in detecting obstacles. The ability to detect obstacles with it appears to be independent of any previous experience of echolocation. This result by itself suggests that the device might be useful as a mobility aid, especially for those blind people who have not become proficient in echolocation (those who are newly blind). However, as Beurle (1951b) and Graystone and McLennan (1968) have suggested, there are several factors which militate against the use of such a device as a general mobility aid. Blind people, like the rest of the population, dislike attention being drawn to them particularly if it reflects a disability, and might well reject the carrying of an audible sound source. The device becomes far less effective when there is a high level of ambient noise, thus reducing the advantage of the device in situations where it is most needed (busy streets, noisy shops, offices, or municipal buildings). Also as Graystone and McLennan (1968) suggest, most blind people prefer to have both hands free. This is not a serious objection, as the device could easily be mounted elsewhere, such as on the chest, although this might require automatic scanning. Head mounting would facilitate scanning but would be objectionable from the cosmetic aspect, as the source size required could hardly be accommodated within spectacle frames. Alternatively, a sound source might well be mounted in the handle of a long cane, or even at its tip.

Experience gained in the study reported above has indicated possible improvements to the device for more general use. The aid could be made considerably smaller, with its own power supply incorporated. It could then be stored in pocket or handbag until required for use. Although a form of electronic, or mechanical scanning might be advantageous, there is merit in the user taking an active role in data acquisition. It would be worthwhile to include an automatic volume control to adjust to environmental noise level.

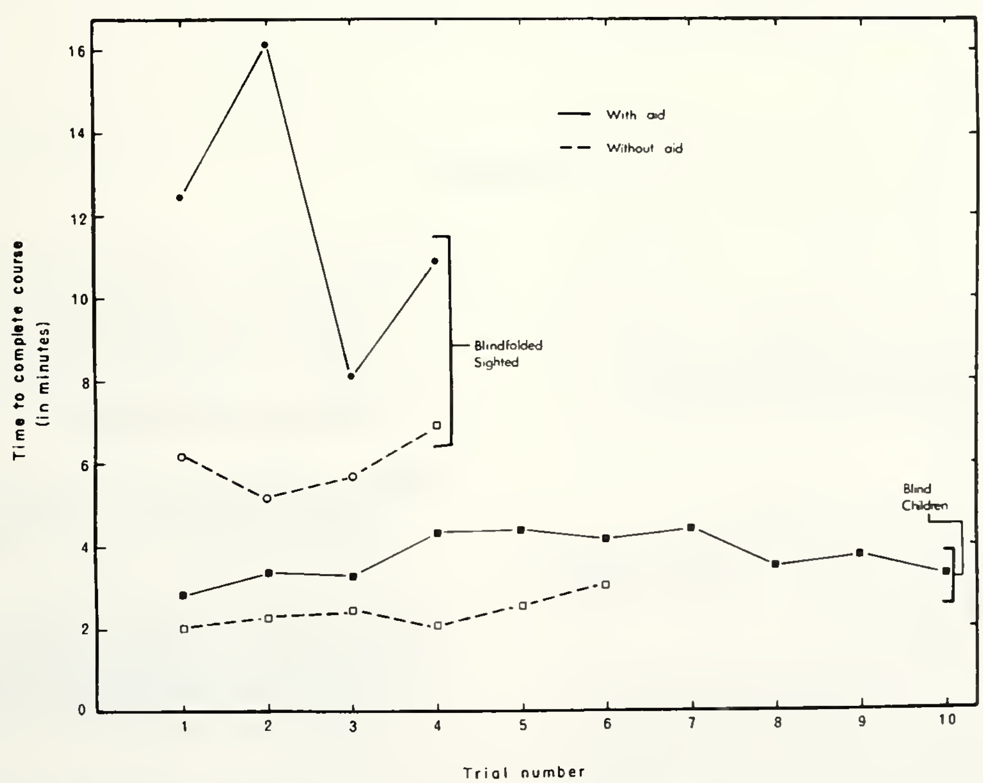

Figure 9. Time to Complete Obstacle Course With and Without Aid.

The device provided a greater range of perception of the world which would tend to increase confidence in the less mobile blind. The experiments suggested that the aid would be of considerable assistance in detecting a wide variety of street "furniture," although probably not a downstep or a parked bicycle. The implications of Experiment II, which showed that obstacles became "invisible" if tilted, might not be as serious in a real-life situation where reflections are also obtained by means of ambient sound and multiple reflections, and the user is not stationary within the environment. The implications of Experiment III, showing poor absolute distance judgment, indicated that acoustic images tend to predominate over reflection tones but this may not be the case when the subject is in motion and dynamic clues are available (Wilson, 1966). The surprising and encouraging result of Experiment IV, that children who had been blind for many years more than doubled their original unaided detections on the experimental course suggested that explicit training in echolocation using an aid such as that described here might be of use to many blind people.

In conclusion, we would like to reiterate the little heeded words of Beurle (1951a), written over 20 years ago, with regard to echolocation ". . . the desirability of deliberately training blind people in the art of 'getting about' cannot be too highly stressed."

ACKNOWLEDGEMENTS

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REFERENCES

Ammons, C. H., Worchel, P., & Dallenbach, K. M. Facial vision: The perception of obstacles out of doors by blindfolded and blindfolded deafened subjects. *American Journal of Psychology*, 1953, 66, 519-53.

Bassett, I. G., & Eastmond, E. J. Echo location: Measurement of pitch versus distance for sound reflected from a flat surface. *Journal of the Acoustical Society of America*, 1964, 36, 911-16.

Beurle, R. L. Electronic aids for blind people. *British Journal of Psychology*, 1951(a), 42, 164-71.

Beurle, R. L. Electronic guiding aids for blind people. *Electronic Engineering*, January 1951(b), 2-7.

Beurle, R. L. Pulsed stereophonic ultrasonic aids. In *Proceedings of the Leonard Conference on Research into Visual Handicap*. London: Southern Regional Association for the Blind, 1972, 19-25.

Bilsen, F. A. *On the interaction of a sound with its repetition.* Doctoral Dissertation, University of Delft, 1968.

Cotzin, M., & Dallenbach, K. M. Facial vision: The role of pitch and loudness in the perception of obstacles by the blind. *American Journal of Psychology*, 1950, 63, 485-515.

Fourcin, A. J. The pitch of noise with periodic spectral peaks. In *Rapport 5e Congres International d'Acoustique*, Liege: Ia, B42, 1965.

Gardner, M. B. Historical background of the Haas and/or precedence effect. *Journal of the Acoustical Society of America*, 1968, 43, 1243-48.

Graystone, P., & McLennan, H. Evaluation of an audible mobility aid for the blind. *Research Bulletin 17*, New York: American Foundation for the Blind, 1968, 17, 173-80.

Griffin, D. R. *Echoes of Bats and Men.* London: Heinemann, 1960.

Kay, L. Active energy radiating systems: Ultrasonic guidance for the blind. In *Proceedings of the International Congress on Technology and Blindness*. New York: American Foundation for the Blind, Vol. I, 1963, 137-56.

Kay, L. Spectacles for the blind. In *Sensory Devices for the Blind.* London: St. Dunstan's, 1966, 275-92.

Kellogg, W. N. Sonar system of the blind. *Science*, 1962, 137, 399-404.

Kohler, I. Der "Fernsinn" des Blinden. *Die Umschau*, 1952, 15, 449-51.

Kohler, I. Facial vision rehabilitated. In R. G. Busnel (Ed.), *Animal Sonar Systems*. Jouy-en-Josas, 1967, 187-96.

Rice, C. E., Feinstein, S. H., & Schusterman, R. J. Echo-detection ability of the blind: Size and distance factors. *Journal of Experimental Psychology*, 1965, 70, 246-51.

Rice, C. E. Human echo perception. *Science*, 1967, 155, 656-64.

Stevens, S. S. The relation of pitch to intensity. *Journal of the Acoustical Society of America*, 1935, 6, 150-54.

Supa, M., Cotzin, M. & Dallenbach, K. M. Facial vision: The perception of obstacles by the blind. *American Journal of Psychology*, 1944, 57, 133-83.

Thurlow, W. R., & Small, A. M. Pitch perception for certain periodic auditory stimuli. *Journal of the Acoustical Society of America*, 1955, 27, 132-37.

Twersky, V. On the physical basis of the perception of obstacles by the blind. *American Journal of Psychology*, 1951, 64, 409-16.

Twersky, V. Auxiliary mechanical sound sources for obstacle perception by audition. *Journal of the Acoustical Society of America*, 1953, 25, 156-57.

Wilson, J. P. Obstacle detection using ambient or self-generated noise. *Nature*, 1966, 211, 218.

Wilson, J. P. Psychoacoustics of obstacle detection using ambient or self-generated noise. In R. G. Busnel (Ed.), *Animal Sonar Systems*. Jouy-en-Josas, 1967, 89-114.

Wilson, J. P. High-quality electrostatic headphones. *Wireless World*, 1968, 74, 440-45.

Wilson, J. P. Psychoacoustical and neurophysiological aspects of auditory pattern recognition. In F. O. Schmitt and F. G. Worden (Eds.) *The Neurosciences: Third Study Volume*. Cambridge, Mass.: MIT Press, 1974, 147-53.

Worchel, P. & Dallenbach, K. M. Facial vision: Perception of obstacles by the deaf-blind. *American Journal of Psychology*, 1947, 60, 502-53.

RECOMBINATION AND VISUAL PERCEPTION

Robert B. Welch*
Charles Hallenbeck**
Editors

PREFACE

The Conference on the Recombination Procedure as a Tool for the Study of Visual Perception was held at the University of Kansas, Lawrence, Kansas, on November 16-17, 1973. Our theme for the present conference was, as the title indicates, an examination of the recombination procedure as a technique for the better understanding of visual perception. Because our term for this procedure is little known outside a relatively small group of investigators, some clarification is in order. It was apparently Weiss (1941) who first used the term *recombination procedure*. He meant by it a technique whereby the normal relationship between perception and action is disrupted. A good example is the rearrangement of the visual field by means of optical devices (wedge prisms) placed before the eyes. Of interest to investigators who make use of this technique is 1.) the way in which the organism responds initially to the recombination, 2.) whether or not the organism *adapts* to it (and if so, to what degree), 3.) the nature of the adaptive end state, assuming that adaptation occurs, and 4.) the effect of certain variables upon the rate and/or final level of adaptation that may result.

More generally, it is assumed that by disturbing normally accurate perceptual capacities and forcing their reconstitution (adaptation) it is possible to see more clearly how these capacities operate under normal circumstances. A corollary to this assumption is the belief that the process of adaptation in adult human beings provides a close analog to the original development of normal visual perception in the human neonate. Kohler said (1964, p. 23), ". . . factors which help a system overcome a disturbance are no different from those which play a role in normal development."

While the connection between recombination research and blindness may not be an obvious one, we regard it to be fundamentally important. The fullest understanding of visual loss can only be achieved after the simpler problem of normal vision is fully understood. To assert that visual science has no points of contact with blindness research is to suggest that a separate and unique science applies to a class of individuals.

Perhaps an example will help to clarify the importance of a sound visual science as a kind of context for current work on blindness problems. The discovery that phosphenes can be produced by electrical stimulation of the occipital lobes has led some enthusiasts to adopt a *cinematic* interpretation of the visual cortex. They contend that an artificial sensing and preprocessing system could apply the correct combinations of

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*Department of Psychology, University of California, Riverside, California.

**Department of Psychology, University of Kansas, Lawrence, Kansas.

locus, intensity, and frequency of stimulus to support subjective visual experience in individuals who have lost ordinary vision. The attainment of this goal clearly requires that we know the precise nature of the mediations that support the simple fact of normal sight. Which mediators are retinal? Which are motor? How much of the process of normal vision takes place by means of functions with no clear locus in the occipital cortex? If "edge detection" is enhanced by the action of peripheral ganglea, that fact is essential in the quest to evoke a subjectively similar experience by electrical events farther "up-stream."

The effects of the recombination of sensory and perceptual elements constitute a truly critical set of phenomena for the long-range success, if not the short-term goals, of serious work on visual loss. The means by which the adapting organism restores a sense of ordinary to genuinely extraordinary experiences, techniques for the facilitation of the process, and discovery of barriers to its completion are the kinds of questions which have important consequences for work with the blind and visually impaired. A student in a course in computer methods in psychology once asked what pattern recognition had to do with blindness. The answer to these questions is the same; one cannot possibly claim to understand the one without an intimate knowledge of the other.

There were several reasons for our decision to hold a conference on the recombination procedure. First and most important, was the fact that Ivo Kohler of the University of Innsbruck, was visiting the University of Kansas during the Fall 1973 semester as the University Rose Morgan Professor. This is an endowed professorship, awarded to one foreign scholar each semester. The research of Dr. Kohler (together with Erismann) on adaptation to optically rearranged vision is considered by most investigators to be the primary stimulus for the veritable explosion of research on this topic which was generated among American psychologists during the late 50's and the 60's. We sought to capitalize on Dr. Kohler's presence on our campus by inviting a number of investigators to a conference devoted to an examination of the present status of research on the recombination procedure.

A second reason for calling the conference was that it had been eight years since the last conference of this sort was held (Freedman, 1968). A great deal of relevant research has taken place since the earlier conference at Tufts University, and we hoped that our meeting would serve as a means of assessing what the recombination procedure has taught us to date about perception and, as well, the present-day evaluation of its usefulness as a tool for investigating perception.

Finally, it was an opportune time to look to the future. Had the technique outlived its usefulness? Had certain assumptions or expectations of the technique been unfulfilled? What was the future role of the procedure? These were some questions we hoped would be dealt with during the conference.

Dr. Charles Kiesler, Chairman of the Department of Psychology at the University of Kansas gave the opening address. Ten papers were presented in sequence over the next few days, each followed by discussion. The closing address was given by the guest of honor, Ivo Kohler.

Discussants included Drs. Malcolm Cohen, Thad Cowan, Hubert F. Dolezal, Wayne Hershberger, Lawrence E. Melamed, Gordon Redding, William B. Templeton, James Walker, Benjamin Wallace, George Woods, and Fred Yaffe.

There follows summaries of the ten papers presented at the conference. Because they are summaries, there was liberal condensation, and many details were omitted. We take full responsibility for any inadvertent misrepresentation or oversimplification. The papers varied in content. Some dealt with a few studies and others with many. Research varied from previously published studies to unpublished or preliminary data. In several cases a significant proportion of the paper entailed a discussion of proposed research.

Each summary is followed by a brief presentation of discussion elicited by the talk. Because of

the nature of tape recordings of discussions it was not always clear who was talking, therefore, the names of the discussants have been omitted.

ACKNOWLEDGEMENTS

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An Introduction to the Typical Paradigm of a Study Using the Recombination Procedure

Because the reader may be unfamiliar with the procedural details of studies involving the recombination procedure it is probably useful to describe a typical paradigm, the one used (with minor modifications) in most of the research presented at the conference.

Typically, testing begins with measures of *S*'s normal perceptual and/or perceptual-motor capacities such as target-pointing accuracy, prior to imposing a rearrangement. This, then, represents a baseline measure and is usually taken in such a manner that *S* receives no feedback about his performance. In some instances this "before" measure is taken just after the perceptual rearrangement has been imposed, but again no feedback is allowed. After the "pre-exposure phase" is completed, *S* is exposed to the consequences of his actions in the perceptually rearranged environment. This represents the "exposure," or "adaptation," phase, its length varying in different studies from a few minutes to many days. Depending on the study, the postexposure measures may be taken at intervals during the exposure period, at the end of the exposure period, and/or at various intervals after exposure is terminated. In any case, all feedback (perceptual or otherwise) is precluded, as was true in the pre-exposure phase.

Typically, the dependent variable is the difference in perceptual and/or perceptual-motor performance between the pre-exposure phase and the post-exposure phase. If the shift is statistically significant and expecially if it serves to compensate for the effects of the rearrangement, it is assumed to have been caused by the rearrangement and is termed adaptation. Naturally, it is necessary to include a control group (for example, one exposed to a normal perceptual environment) for the purpose of comparison. If *S*'s perceptual field is not rearranged at the time that the pre- and postexposure measures are taken, a "pre-post" shift is often referred to as the "negative aftereffect." If, on the other hand, measures are taken at the beginning of the period of rearrangement and again at some later time while the rearrangement remains, an observed adaptive shift may be referred to as the "reduction of effect." It is not clear that these two kinds of shifts are directly comparable.

Prism Adaptation: Learning Aspects and Proprioceptive Contributions

Edward Taub and Israel A. Goldberg

Institute for Behavioral Research, Inc.

In this paper Taub discussed a series of studies which he and his associates have carried out over the last decade. The studies have in common the aim of assessing, by means of various types of recombination procedure, the role of sensory feedback upon the learning and performance of motor skills. Three complementary research strategies were used: 1.) somatosensory-deafferentation, 2.) adaptation-to-sensory-rearrangement and 3.) combined deafferentation and sensory rearrangement. Both human beings and monkeys served as *S*s in this research.

The Somatosensory-Deafferentation Experiment

Taub and his colleagues surgically eliminated sensation from various portions of the monkey's body and then, after recovery, assessed the amount of movement and motor learning demonstrated by the animal in various situations. With adolescent monkeys he (and others) found that if one forelimb is deafferented (by means of dorsal root section), it is effectively useless unless there is sufficient motivation and/or the *intact* limb is restrained. Interestingly, Taub et al. showed that if *both* forelimbs are deafferented (by means of bilateral dorsal rhizotomy), the animal demonstrated spontaneously quite adequate (although not completely normal) usage of these limbs for grasp, ambulation, and climbing, both while able to see and while blindfolded. These capabilities remained intact even following complete deafferentation of the spinal cord.

Thus, in contradiction to some well-known theories concerning the nature of movement and learning, it seems clear that somatosensory feedback is not necessary in order for adolescent monkeys to learn and to perform movement.

In order to see if the preceding conclusion also held for immature organisms Taub et al. subjected four moneky infants to bilateral forelimb deafferentation within hours after birth. These animals spontaneously developed the behaviors of ambulation, climbing, and reaching for objects, all of which were as good at three months of age as in monkeys deafferented in adolescence. Furthermore, with special training it was possible for grasp, individual finger use, and precise hand-eye coordination to be demonstrated. On the day of birth, two additional rhesus infants were given both bilateral forelimb deafferentation and occlusion of vision (sewing the eyelids closed). The elimination of vision had only a small effect (1-2 week retardation) on the development of general motor coordination of the forelimbs such as supporting the body weight, walking, or clasping objects, as compared to the nonblinded deafferented animals. On the other hand, the blinded deafferents, not unexpectedly, revealed an inability to engage in discrete reaching responses (hand-to-mouth). However, special shaping procedures led very rapidly to accurate performance.

Finally, Taub and his associates have attempted to perform limb deafferentation on the *unborn fetus*. The dorsal rhizotomies were performed at the end of the second trimester of prenatal life. The results of this study were equivocal, however, due to the fact that the operation caused the spinal cord to become flattened and otherwise deformed, thereby resulting in what was essentially a "spinal preparation." Nevertheless, these animals developed the ability to use the forelimbs for pushing themselves into a sitting position, and for crude ambulation. Further research will include techniques designed to prevent damage to the spinal cord.

Adaptation to Sensory Rearrangement Studies

In this second type of study intact human subjects were confronted with an optically rearranged visual environment and their response to the situation noted. More specifically, Taub and his colleagues exposed *S*s to a visual field which, by means of wedge prisms, was displaced laterally by approximately 11°. The ability to adapt to the visual rearrangement and the nature of this adaptation were measured in a variety of conditions.

Taub's laboratory had produced a number of studies designed to test the view that adaptation to optical rearrangement is an example of *learning* and not (as some have argued) a special or "more primitive" process. The research by Held and Freedman (1963) suggested that prism adaptation is *not* learning, because it was found to occur even when *S* received no error-corrective feedback. *S*s in many of Held's studies were allowed to observe through the prism their actively moving limbs, but no target was provided. Because they were precluded from making errors (punishment) or correcting for them (reward) there appeared to be neither a motive nor a reward contingency for the prism adaptation that nevertheless resulted. Taub, however, suggested that the motive might be the aversive character of sensory discordance. That is, the presence of sensory rearrangement is aversive to an organism because in the past this state has been associated with punishing consequences (misreaching, running into obstacles). Avoidance or escape from the presence of sensory discordance is, therefore, *secondarily* rewarding. Since adaption serves to reduce or eliminate the discordance, it represents a response that leads to a reward and therefore fits neatly into the traditional learning paradigm. Crucial to this argument is the fact that adaptation will be induced merely by *S*'s perception that a sensory discordance exists; it is not necessary that *S* actually experience an error in reaching or in navigating obstacles.

One study reported by Taub which represents a direct test of his learning theory of prism adaptation showed that the reduction of sensory discordance is, indeed, a reinforcing event. In this experiment *S* was required to move the right arm from side to side. As he viewed the limb through a prism whose strength could be varied. In one condition the degree of optical displacement was reduced if *S* increased the rate of arm movement; in the other condition the reduction in sensory discordance was contingent upon a decrease in rate of movement. If there was no change in rate or a change opposite to the desired one, the result was an *increase* in optical displacement. It was found that (unbeknownst to *S*) rate of arm movement would either increase or decrease when such a change led to a reduction in the prism strength, thus providing support for the hypothesis that such a reduction represents a rewarding state of affairs, which strengthens a response tendency.

Another category of evidence which can be used to support the contention that prism adaptation is an example of learning is a demonstration that it is affected by certain "learning variables" in the same manner as are "traditional" learned behaviors. One such variable is the distribution of practice. It is well known that "massed practice" leads, at least initially, to poorer performance than is the case if trials are distributed over a longer time interval. Furthermore, at least for certain motor tasks, intermanual transfer of a skill is retarded or eliminated by the massing of trials.

Taub reported a study in which prism exposure trials were either massed or distributed. The results indicated that distributed practice (ten 30-second exposure periods evenly distributed over 9.5 minutes) led to greater adaptation than did massed practice (ten 30-second exposure periods with no intervening rest periods). Also, as predicted by the learning theory hypothesis, intermanual transfer of prism adaptation occurred only with distributed practice.

In another experiment, Taub et al. demonstrated that the well-known absence of prism adaptation when *S*'s limb is moved *passively* (Held and Hein, 1958) does not occur if the passive movement is coupled with distributed exposure periods. Nevertheless, active movement (whether massed

or distributed) induced more adaptation than did passive movement, thus indicating that active movement enhances, but is not (as Held and Hein have maintained) necessary for adaptation.

<u>Combined Deafferentation and Sensory Rearrangement Studies</u>

In this third type of experiment *S*s (monkeys) were both deafferented and exposed to a prismatically displaced visual field. The specific aim of the study which Taub described was to examine the hypothesis of Harris (1965) and others that the prism-adapted state is one of altered proprioception (or, more appropriately, *position sense*), rather than of a change in visual perception. If this hypothesis is correct, then the surgical elimination of proprioceptive afference should significantly affect the rate and/or final level of prism adaptation.

The monkeys had been deafferented in the neck, shoulders, and arms for a year prior to being trained to reach for a food pellet while seated in a restraining chair. *S* was precluded from viewing the limb throughout each reaching response and at all other times as well. All of the deafferented animals quickly learned to make this response with surprising (although not normal) accuracy. After an accurate and stable performance level was reached, each of the deafferented *S*s, as well as each member of a group of normal animals, was fitted with prism goggles for about 24 hours. They were not allowed to see any part of the body, but the head could move freely. As measured by aftereffect, adaptation was 39 percent of full prism displacement for the normals but 100 percent for the deafferents.

Dr. Taub argued that there are *two* forms of felt body position: 1.) proprioception or somatosensory feedback, and 2.) central feedback or central efferent monitoring. The first is afferent, the second efferent. Clearly, the surgical operation served to eliminate only the afferent type of body position sense. Because this procedure led to facilitation of prism adaptation Taub et al. argue that the presence of proprioception in the normal animal inhibits or delays adaptation. That is, the less there is of position sense the easier it is to alter.

The evidence from this study clearly supports the view that, at least in the prism-wearing situation, adaptation is primarily or totally a matter of recalibrating the body position sense (which could include felt *eye* position). A vision change hypothesis would predict less, not more, adaptation after deafferentation, since this results in making felt body position less salient and, therefore, presumably less effective in modifying visual localization.

DISCUSSION

During the discussion period several issues were raised with respect to the deafferentation studies (with and without visual rearrangement). Of particular interest was the question of *how* it was that a deafferented monkey could learn to reach for unseen objects (as when also blinded) or to adapt to prism displacement. Taub argued that in both instances it is clear that a *central* (efferent) form of position sense must be involved, in that proprioceptive afference from the body parts in question had been eliminated by means of the operation. If a deafferented and blinded monkey can learn to reach accurately for its mouth it must be because the efferent commands for the correct response are registered centrally and reinforced (by ingestion of the food object in the monkey's hand). If the deafferented monkey demonstrates adaptation, it cannot be due to a change in proprioception but rather in the central form of position sense. Because only one of the normally two types of position sense is present, prism adaptation should be enhanced--and, in fact, it was 100 percent.

Discussants expressed uncertainty regarding the precise body part that was involved in the adaptation and the nature of the cues of sensory discordance that induced it.

Because the head was free to move and was *not* deafferented (while the neck forelimbs, and upper extremities of the trunk were) Taub suggested that adaptation may have involved a recalibration of (central) position sense in terms of the relationship between the head and the remainder of the body. Possibly, the neck muscles represented the specific locus of adaptation. Such a change, if completely adaptive, would lead the animal to reach accurately for objects (with either limb). Because the monkey was precluded from a view of any part of its body, the sensory cues for adaptation must have resulted from the various visual effects that occur during head movement.

There was general agreement that Taub's learning model of prism adaptation has been useful in that it has forced investigators to examine and operationally define such parameters as exposure trials and intertrial intervals and has generated a number of interesting experiments. Questions were raised, however, with respect to its usefulness as an explanatory concept. In particular, several of the discussants were unclear as to *why* distributed practice should facilitate ipsilateral adaptation and lead to intermanual transfer. Merely noting the fact that the results are the same or similar to those found with "traditional" tasks, such as the pursuit rotor, does not explain the finding. It was suggested by one discussant that a useful explanation might entail the notion that different kinds of exposure condition, such as massed vs. distributed practice, lead to differential selective attention to visual and proprioceptive cues, which in turn lead to different magnitudes and/or types of adaptation. Uhlarik and Canon (1971) have proposed such a model.

Processes Involved in Behavior Observed in Recombination Studies

George Singer, Meredith Wallace, and Margaret Austin

Latrobe University

George Singer's address consisted of a detailed presentation of a number of studies carried out in his laboratory, supporting a three-component model of adaptation to optically-induced tilt. Singer began by stating that the end product of adaptation to rearranged vision is not a unitary entity, but rather the sum (or product?) of several qualitatively different components: behavioral compensation (BC), sensory spatial adaptation (SSA), and visual shift (VS). BC is the acquisition of an adaptive motor response and is, therefore, an example of motor learning. It should reveal the characteristics of learning. That is, it should: 1.) require knowledge of results, 2.) increase with practice, 3.) transfer to other situations, and 4.) persist for some time in the absence of reinforcement. The amount of BC which will occur in a given situation depends upon 1.) the extent of the transformation (if the rearrangement is relatively minor, and therefore undetected, no change in motor response "rules" will be elicited), 2.) the nature of the task (e.g., the presence of error-corrective feedback facilitates motor learning), and 3.) the number of trials (the more trials, the better learned the response).

SSA, unlike BC, can occur as a result of prolonged, unchanging stimulation of a single sensory system, dissipates relatively rapidly, and *does not depend on discordant information.* The "figural after-effect" (Kohler and Wallach, 1944) is an example of this form of adaptation. Another, more relevant, example is

the reduction in perceived curvature of objectively straight lines when passively viewed through a prism for a period of time. This sensory adaptation leads to a negative aftereffect upon removal of the prism--the lines appear curved in the opposite direction. These aftereffects are short-lived (2-3 minutes). The same effects occur with the inspection of *objectively* curved lines, which demonstrates that sensory rearrangement is irrelevant for this form of adaptation, and that it is probably confined to the visual system. Analogous results have been reported in the kinesthetic modality (Heinemann, 1961).

VS, the third component of adaptation, is an apparent reduction of the visual rearrangement (and/or a visual aftereffect upon removal of the optically transforming device). It is a purely visual change with a longer duration than is the case with SSA. VS may occur in the absence of BC and vice versa.

In the first experiment reported in detail by Dr. Singer the rearrangement used was *optical tilt*, effected by means of two Dove prisms in tandem. The *S*'s task before, during, and after exposure was to set (by means of a control knob) a bar to the apparent horizontal in terms of *kinesthetic* information. The exposure period involved stimulation of kinesthesis alone, vision alone, or the simultaneous stimulation of both sensory modalities. There were seven conditions in the experiment. Group 1 received kinesthetic stimulation from a horizontal bar but no vision, while Group 2 received both kinesthetic and visual stimulation from the horizontal bar. Neither of these two groups was expected to reveal either SSA, since the bar was horizontal, or BC, due to the absence of sensory discordance. Group 3 received kinesthetic stimulation from a 20° tilted bar but no vision and was therefore expected to reveal SSA but no BC. Group 4 experienced kinesthetic stimulation from a horizontal bar plus visual stimulation from the same bar, optically tilted by 20°. For this group the fact that the bar was horizontal led to the prediction of no SSA, while the presence of the 20° sensory discordance meant that BC should result. Group 5 received kinesthetic stimulation from a 20° tilted (up or down) bar,plus visual stimulation from the same bar made to *appear* horizontal by means of the prisms. This condition was expected to induce both SSA and BC in the same direction; they should summate. Group 6 was exposed to kinesthetic stimulation from a 10° tilted bar plus visual stimulation from the same bar made to *appear* tilted 20° from the horizontal in the same direction as the 10° physical tilt, giving a net sensory discordance of 10°. It was predicted that this group would reveal SSA and BC, but in *opposite* directions (thus partially or totally cancelling each other). Finally, Group 7 received kinesthetic stimulation from the bar tilted physically by 10° from the horizontal (either up or down) plus visual stimulation from the same bar optically tilted 10° from the horizontal in the direction *opposite* the physical tilt (a net discordance of 20°). In this condition the prediction was that SSA and BC would both develop and be in the same direction.

As can be seen by Table 1, all predictions were confirmed. These data, then, provide support for the existence of two of the three prism-adaptive components postulated by Dr. Singer. As he mentioned in his talk, both SSA and BC probably occur (and summate) in many prism adaptation studies, since both sensory discordance and prolonged exposure to atypical (tilted, curved, asymmetrical, etc.) stimulation are usually present.

The third component, VS, was examined in another experiment. Dr. Singer observed in his talk that the elicitation of VS appears to require, among other things, a relatively large visual field containing various objects. In order to overcome the constriction of the visual field that occurs when Dove prisms are used, a 6' X 6' X 4' room was built which could be physically rotated about the horizontal axis. Thus an upright *S* who views this field is confronted with a discordance between visual and nonvisual cues since the visual frame of reference gives information of tilt, while the vestibular, kinesthetic, and proprioceptive systems give information for upright body position. Two factors were examined in this experiment: trials (either one or ten) and exposure posttest

TABLE 1

Mean Aftereffect and Standard Deviations Obtained from 7 Different Prism Exposure Conditions

Group	Conditions of Exposure Vis.	Kin.	Discordance between vision & kinesthesis	Predictions for adaptation	Aftereffect Mean (deg)	S.D.
1	absent	0°	None	No adaptation	-0.65	2.63
2	0°	0°	None	No adaptation	0.24	2.07
3	absent	20°	None	SSA	2.95	2.33
4	20°	0°	20°	BC	1.97	1.60
5	0°	±20°	20°	SSA + BC	4.92	1.81
6	+20°	+10°	10°	SSA - BC	-0.64	2.58
7	±10°	±10°	20°	SSA + BC	5.71	1.93

delay (adaptation measured immediately after exposure, 5 minutes after exposure, or 15 minutes after exposure). Different *S*s were used in each group.

The room contained various objects, a chair, a picture, and was tilted laterally by 22°. On the back wall of the room was a 24" X 1.5" luminous bar, which could be rotated (by means of a rotary knob) by either *S* or *E*. When seated directly in front of the tilted room, *S* could see nothing else. During the pre- and posttests *S* was required to set the luminous bar to apparent visual vertical (with respect to gravity) in the otherwise dark room. During the exposure phase the lights of the tilted room were switched on and *S* made either one or ten adjustments (at 30-second intervals) of the bar to vertical. Between all adjustments, view of the room was precluded by drawing a curtain. Two of the groups were given the posttest immediately after the exposure trial(s), two were tested after a 5-minute interval and two after 15 minutes. For the two delay conditions, *S* wore translucent goggles between completing the adjustments and undertaking the posttest.

The results are seen in Table 2. All conditions produced adaptation and the effect for trials was statistically significant (more adaptation for 10 trials than for 1). Finally, there was a drop in level of adaptation between the 0-minute exposure-posttest interval and the 5-minute interval but not between the 5- and 15-minute intervals. The drop over the three intervals is more apparent for the 1-trial groups than for the 10-trial groups.

Dr. Singer concluded that this experiment supported the existence of the VS component of prism adaptation, a component that is qualitatively distinct from a visual sensory aftereffect of the Gibson variety since, in contrast to the latter, it did not dissipate even after a 15-minute period. VS is also separable from behavioral compensation, Singer argued, because in the present experiment there was no behavioral interaction with the sensorily discordant field. Another characteristic of the adaptation found in the tilted room situation is the fact (based on a published study) that it leads to complete *intermanual* transfer of motor responses, clearly supporting the notion that this component consists of a change in the visual system.

TABLE 2

Mean Aftereffect and Standard Deviations Following Exposure to a Tilted Room

Group	No. of Adjustments	Delay before Posttest	Mean a/effect (deg)	Standard deviations
1	1	No delay	3.93*	2.00
2	10	No delay	4.14	2.34
3	1	5 min.	2.20	2.52
4	10	5 min.	3.37	2.77
5	1	15 min.	2.54	2.39
6	10	15 min.	4.05	4.64

*All deviations were in the same direction as the room tilt.

DISCUSSION

Singer was asked if he felt that the different components of tilt adaptation ever *interacted*. In particular, would an increase in one component lead to a balancing decrease in another? He said that he has not yet specifically investigated this possibility. Thus, as it stands now, his is an *additive* model.

In response to another question, he argued that it was quite unlikely that in the VS study (the second experiment described) any sensory adaptation to the visual tilt could have taken place along with the VS. The reason for this belief is that the actual exposure to the tilt (approximately 5 seconds for the 1-trial groups and 50 seconds for the 10-trial groups) was too short to lead to much if any sensory spatial effects.

An important question was raised concerning the generalizability of Singer's results and model from visual tilt adaptation to the more typical experiment in which the visual field is laterally *displaced*. More specifically, it was asked if he felt that SSA was really a factor in the prism-displacement study, since visual asymmetry is typically controlled for (and curvature of tilting of contours is irrelevant for the types of prism-adaptive measure usually taken). Singer's response to this question was that indeed there are sources of relevant sensory spatial adaptation in the prism-displacement study, in terms of *kinesthesis*. That is, when *S* interacts with a prism-displaced field by, say, reaching for objects, he may well develop a chance in kinesthesis which will persist to influence (add to or subtract from) the adaptive shift measured.

Finally, it was pointed out that a change (from fatigue, muscle potentiation, etc.) in felt head and/or eye position could and apparently does lead to a change in visual straight ahead, although it is not clear that this is identical to the visual shift which Dr. Singer has measured. Relevant to this point, Dr. Singer discriminated between a *muscular* adaptation and adaptation of the joint receptors (which may cancel each other).

Some Effects of Exposure to Optical Disarrangement on Adaptation to Optical Rearrangement

John J. Uhlarik

Kansas State University

Two recent, unpublished studies on adaptation to prism-displaced vision are described in detail here. *Rearrangement* of the visual field represents a stable and relatively isomorphic change in which the normal correspondence between felt and seen body position is disrupted, at least initially. Adaptation to such a situation is a possibility. *Disarrangement*, on the other hand, represents a situation in which the nature and/or extent of optical distortion is in a constant state of flux. That is, the relationship between felt and seen body is ambiguous or unspecified. If this change is *random*, it is impossible for adaptation to occur. Held and Freedman (1963) report a study which found that even if the changing state of optical rearrangement is systematic, no adaptation will result. The aim of the present studies was to examine some implications of the "comparator" or "coordinator" model of prism adaptation. In brief, the role of a comparator is to monitor, and hence to control, the level of adaptation in terms of the relationship between 1.) the *stored* correlations (between felt and seen body position) from previous viewing situations and 2.) the inputs from the present viewing condition. In order to further specify some qualitative and quantitative properties of this kind of mechanism the studies reported by Uhlarik examined the effects of exposure to conditions of disarrangement on the level of adaptation to subsequent conditions of rearrangement. Various models and assumptions lead to predictions that pre-exposure to disarrangement will facilitate, will retard, or will have no effect upon the level of subsequent adaptation to rearrangement in comparison with a condition of pre-exposure to normal viewing conditions. Clearly, the outcome of the present experiment has important theoretical implications.

The first experiment compared two conditions: pre-exposure to disarrangement and pre-exposure to normal viewing. Following the pre-exposure period, *S*s in both conditions were exposed to 11° lateral prism-displacement and then measured on their level of adaptation in terms of 1.) vision, 2.) felt limb position, and 3.) target-pointing accuracy (the visual-proprioceptive measure). During both the pre-exposure and exposure viewing periods *S* reached for visual targets at a steady, fixed rate while continuously viewing the moving limb. Thus, both error-corrective feedback and experience of the relationship between felt and seen body position were present. Short rest periods occurred every 2 minutes. The disarrangement pre-exposure viewing situation involved observing the targets (and the target-pointing attempts of the arm) through two counter-rotating Risley variable prisms, placed in tandem in front of the right eye. The net effect was of a visual field continuously changing in its lateral displacement from 17° to the left through 0° (straight ahead) to 17° right and back again. The full cycle took exactly 1 minute. In addition to the factor of type of pre-exposure viewing condition were the variables of exposure duration (10 min./20 min.) during the pre-exposure phase and prism orientation (base left/base right) during the rearrangement period.

Measures of vision, felt limb position, and target-pointing accuracy were taken before and after the pre-exposure viewing period and immediately after the rearrangement period. During each of these three test periods vision was normal and feedback about performance was precluded. The measure of visual location entailed the setting (by *E*) of a dot of light to *S*'s perceived straightahead position in the otherwise dark room. The

measure of felt limb position required that *S* place his unseen arm in such a manner that it was felt to be straight ahead of his nose. The final measure required *S* to point at a series of visible targets, again with no visual feedback from the pointing limb. The order of the visual and proprioceptive measures during a given test period was counterbalanced across *S*s, while the target-pointing measure always came last.

The data of primary interest were the differences between the measures taken before and after rearrangement. These scores represent the prism-adaptive aftereffects and are presented in Table 1. While both proprioceptive and target-pointing shifts generally were significant, only in one condition was there a measurable change in vision. The general failure to find visual adaptation agrees with previous studies which, like the present one, used a concurrent display condition. The table shows that the adaptive proprioceptive and target-pointing shifts were greater in the normal viewing condition than in the disarrangement condition, especially when exposure was for 20 minutes. The two conditions did not produce differential visual adaptation. The apparent interactions between the type and duration of the pre-exposure viewing periods were not statistically significant for either the proprioceptive or target-pointing measures.

Finally, it was found, contrary to results reported by Held and Freedman (1963), that exposure to disarrangement did not lead to an increase in variability of target-pointing accuracy (or in the other two measures either). Furthermore, no relationship was found between 1.) the amount of *change* in variability between the tests taken before and after exposure to disarrangement and 2.) the level of subsequent adaptation to rearrangement.

In sum, the data of the first study suggested to Uhlarik that the comparator must act as an *autocorrelator*. Disarrangement serves to

TABLE 1

Mean Adaptive Shifts in Degrees Between Test 2 and Test 3 for the Concurrent Display with Target Exposure Conditions

		Measures		
		Visual	Proprioceptive	Visual-Proprioceptive
Preexposure Conditions	10 min.	1.4	2.1*	2.5*
Disarrangement	20 min.	2.2*	0.8	2.1*
	10 min.	1.1	3.1*	4.2*
Normal Viewing	20 min.	1.1	3.9*	4.7*

*Denotes values significantly different than zero, $p < 0.05$ (based on two-tailed t-tests)

introduce noise or error into the system which interferes with the autocorrelation process.

It is possible that the failure to replicate the finding of increased dispersion of localizations as a result of disarrangement was due to the presence of error-correcting feedback in the present experiment. Consequently, a second study was carried out in which *S* was exposed only to the discrepancy between felt and seen position of the limb. That is, no targets were present, thus precluding error-corrective feedback. *S* merely moved the limb in and out, viewing it continuously during both pre-exposure and exposure viewing situation. This is similar (although still not identical) to the procedure used in the disarrangement study reported by Held and Freedman (1963). The rest of the design and procedure were the same as in the first experiment, except that all *S*s received a 10-minute exposure period.

The results are seen in Table 2. Both the visual and visual-proprioceptive measures were statistically different from zero in the disarrangement condition, while none of the measures was significant in the normal viewing condition. However, in no case was there a significant difference between disarrangement and normal viewing. Furthermore, no reliable increase in variability of localization was noted subsequent to disarrangement for any of the measures. It is unclear why it was that even with no-target exposure there was a failure to replicate previous findings of systematic increases in the variability of pointing localizations following exposure to disarrangement.

To conclude, the data from the first experiment indicate a retarding effect of exposure to disarrangement upon subsequent adaptation to rearrangement, while the second study found no such effect. This difference in results suggests that there

TABLE 2

Mean Standard Deviation of the Visual, Proprioceptive, and Visual-Proprioceptive Measures for the Three Tests for the Concurrent Display with Target Exposure Conditions. (Numbers in parentheses indicate correlation coefficients between the magnitude of the adaptive shifts [Test 3 - Test 2] and changes in variability due the pre-exposure periods [SD for Test 2 - SD for Test 1])

			Measures		
			Visual	Proprioceptive	Visual-Proprioceptive
Preexposure Conditions					
	10 min.	Test 1	1.9	1.2	1.9
		Test 2	2.1 (0.01)	1.2 (0.21)	1.4 (0.18)
		Test 3	1.6	1.0	1.5
Disarrangement					
	20 min.	Test 1	2.0	1.6	1.8
		Test 2	2.4 (0.08)	1.3 (0.20)	1.6 (-0.67)
		Test 3	1.8	1.4	1.6
	10 min.	Test 1	1.5	1.4	1.9
		Test 2	1.5 (-0.50)	1.2 (0.48)	1.6 (0.28)
		Test 3	1.5	1.3	1.3
Normal Viewing					
	20 min.	Test 1	2.0	1.6	1.6
		Test 2	1.7 (-0.07)	1.3 (0.07)	1.2 (-0.26)
		Test 3	1.5	1.2	1.1

might be important differences in the manner in which information regarding intermodality discordance and target-pointing error is processed by the comparator.

DISCUSSION

This paper elicited a very active discussion, both during and after presentation. One of the major issues raised was Uhlarik's failure (even in the no-target situation) to replicate the previously reported (Held and Freedman, 1963) increase in variability of localization due to exposure to disarrangement. It was suggested that this failure might have vitiated the study. However, it is more important to consider possible reasons for this failure to replicate. A number of suggestions were offered. The second experiment was designed to handle many of the obvious differences (target-pointing errors, use of strategies, possible failure to pay close *attention* to the limb as it moves) between the first experiment and that reported by Held and Freedman (1963). Nevertheless, some potentially important differences remained in the second study. One of these is the fact that Uhlarik used far fewer trials during the postexposure tests than was the case in the original disarrangement study (12 target-pointing measures vs. 40). It is possible that the increase in localization variability induced by disarrangement requires a longer period of postexposure time to be manifested than was provided by Uhlarik's procedure. If this point is valid it suggests that Uhlarik's studies were, in fact, successful in their aim of inducing variability in localization, but that their measures were unable to detect it.

Because it is not clear that Uhlarik was successful in creating a "decorrelated" state in *S*s exposed to disarrangement, several alternative procedures were proposed. One was to use a *randomly* (rather than systematically) changing prism strength while simultaneously making the target always appear to be straight ahead (by physically changing its position in the direction opposite the prism displacement). This would make it impossible for *S* to use a conscious strategy of pointing straight ahead. A second, related, technique is to allow *S* to "hit" the target on every trial, no matter where he points. This situation could be effected by physically moving the target to wherever *S*'s finger had aimed. If one or the other of these procedures induced increased variability in target-pointing localization, one could then repeat Uhlarik's design with more confidence that the comparator had been affected in some way.

The fact remains, however, that in the first experiment exposure to disarrangement appeared to retard adaptation to rearrangement when compared to the situation in which prior viewing was normal. Several potential explanations of this result were put forth. Uhlarik suggested that this may support the hypothesis that adaptation is a process of autocorrelation and that disarrangement adds "noise" to the system, making autocorrelation more difficult. Another possibility that was raised is that the actual discordance experienced was greater for *S*s with prior normal viewing than for *S*s in the disarrangement condition because the latter situation gave *S*s experience with displacement (albeit, constantly changing). Thus, there is a greater "contrast" between the experiences of normal viewing and rearrangement than between disarrangement and rearrangement. This "contrast effect" might induce a more vigorous adaptation response.

The Subject: A Neglected Factor in Recombination Research

David H. Warren and Bruce B. Platt

University of California, Riverside

David Warren began by pointing out that the contradictory results often reported in the area of recombination research (particularly prism adaptation) may be due to individual differences in perception. In addition, he argued that by looking for correlations between "perceptual traits" and level and type of adaptation to rearrangement one might come to a better understanding of the nature of the adaptive process. A disturbing possibility is that such hypothesized perceptual characteristics *interact* with the independent variables of a given experiment. As an example of a relevant individual difference, when *S*s are allowed to point at a target with continuous view of the moving limb, some individuals (for whatever reasons) may fixate the hand throughout its movement, while others might spend most of the time fixating the target. In effect, the *S*s would not be in the same condition, since the former individual would receive truly continuous exposure while the latter experienced something akin to "terminal exposure."

Studies that have deliberately examined individual differences in adaptation to perceptual rearrangement are rarely found in the literature. Subject differences may be relevant for the "multi-component" models of prism adaptation which several investigators have proposed (Hay and Pick, 1966; Wilkinson, 1971; Singer, this conference; Welch, this conference). For example, it may be true that prism-induced aftereffects of setting a bar to horizontal are the sum of behavioral compensation and sensory spatial adaptation (Singer). Yet, some *S*s may tend to acquire a great deal of the first component and very little of the second; for others just the reverse may be true. Similarly, it is possible that *S*s differ in their sensitivity to the various *sources* of adaptation. Thus, one *S*, perhaps due to a particular perceptual history, may be quite sensitive to the discrepancy between seen and felt limb position, while another is attuned to target-pointing errors. Both the amount and type of adaptation achieved by these two hypothetical individuals might be quite different.

The experiment described by Warren involved the evaluation of the adaptation of the right hand to lateral displacement of the visual image and of the transfer of that adaptation to the left hand. The *S* sat at an apparatus which was similar to the type used in most previous studies of prism adaptation. During prism exposure he viewed the scene through a 10° base right-wedge prism and made pointing responses under a horizontal shelf at various fixed targets. Visual feedback occurred only at the terminus of each pointing response. A major addition to Warren's testing apparatus was a "trolley" which ran along a track placed beneath and parallel to the horizontal shelf. The track was attached to a boom that rotated around an axle mounted under the chinrest. *S*'s right index finger rested in this trolley and as he moved his pointing hand in and out at the various targets a potentiometer system recorded continuously the radial direction of the boom while, at the same time, a series of microswitches along the boom recorded the proximal-distal position of the "trolley." Thus, it was possible to record continuously (on a Beckman dynograph) the details of *S*'s pointing responses throughout the experiment. Also used was a Beckman direct current electro-oculography system to monitor lateral eye position continuously.

The step-by-step procedure of the experiment entailed eight temporally

ordered tasks. In Task 1 *S* pointed with his right hand at each of six visual targets, with vision displaced, but no feedback provided. Task 2 was identical to Task 1, except that the left hand was used. In Task 3, *S* pointed repeatedly with the right hand at a visual target which was placed to the right of center but appeared to be straight ahead because of the 10° base right-wedge prism which was now before *S*'s right eye. Visual feedback was provided in this task and, hence, adaptation to the prism displacement was expected to occur. If *S* made five consecutive pointing responses within 2° of the visual target, he was then given three additional trials and Task 3 was ended. A maximum of 20 trials was allowed. Task 4 consisted of four trials pointing with the left hand, with vision still displaced but no error-corrective feedback provided. Thus a comparison of Task 2 and Task 4 performance provided a measure of the amount of adaptation acquired by the non-prism exposed limb. Task 5 was included to regain any loss of adaptation of the right hand that might have occurred during Task 4. It consisted of a maximum of 12 right hand adaptation trials, as in Task 3. Task 6 consisted of four trials pointing with the right hand, with displaced vision, but no feedback. Comparison of Task 6 with Task 1 thus provided a measure of right hand adaptation. After Task 6 the prism was replaced with a clear glass aperture. Task 7 was identical to Task 3 except that there was now no discrepancy between the actual and apparent locations of the target. A maximum of 20 trials was given, and the same criterion of accuracy was used as in Task 3. Task 7, then, represented an "unlearning" or "readaptation" phase. Finally, Task 8 required four trials pointing with the left hand to a visual target with no feedback.

A graphic representation of the group results appears in Fig. 1. The curve in the left-hand side of the figure indicates the development of adaptation from Trial 1 to Trial 19. It is clear that *S*'s initial error of pointing straight ahead (90°) at a target actually located 10° to

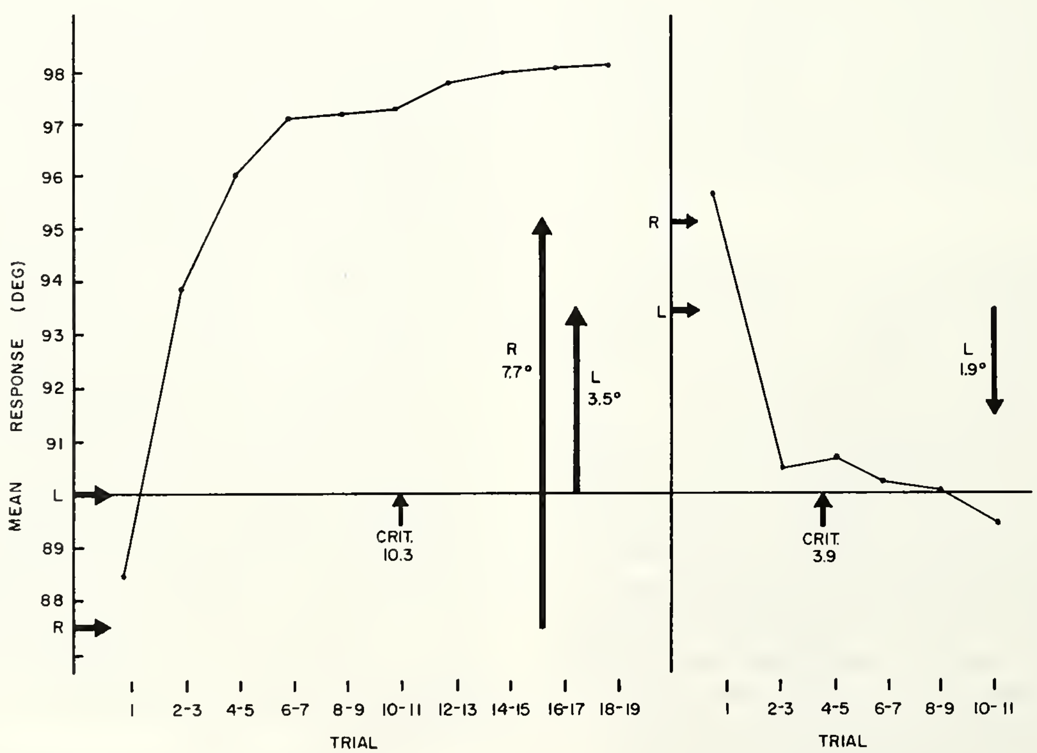


Figure 1. Mean Pointing Response Over Trials for Adaptation to 10° Prism (Left Portion) and for Readaptation to Clear Glass (Right Portion)

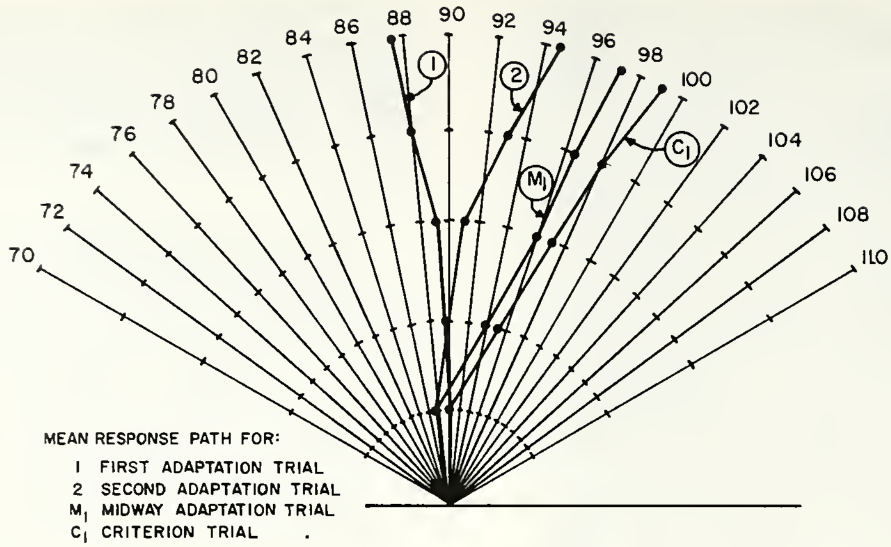
the right (100°) was quickly overcome, the average number of trials to criterion being 10.3 (SD = 6.2). Adaptation as measured in terms of the difference between pre- and post-adaptation measures of no-feedback target-pointing accuracy is indicated by the two vertical arrows. It can be seen that adaptation occurred for both the exposed (right) and nonexposed (left) hand, but was significantly greater for the former. The shift for the left hand represents intermanual transfer. The right half of Fig. 1 depicts the "unlearning" or "readaptation curve" which resulted when the prism-adapted *S* was exposed to normal vision and error-corrective feedback (Task 7). The curve falls quickly, mean trials to criterion being 3.9 (SD = 2.9). The heavy vertical arrow depicts the difference between postadaptation target pointing accuracy for the left hand and accuracy after the "readaptation" period. That is, it represents the mean intermanual transfer of "readaptation" to the nonexposed limb. This transfer was significantly greater than zero.

In addition to exposing *S*s to the eight tasks, detailed recordings and analyses of the exact nature of his hand and eye movements before, during, and after each pointing response were made by means of the trolley-boom apparatus and electro-oculography system described earlier. These measures represented what Dr. Warren referred to as the "microanalysis." Secondly, the testing period was preceded by a battery of pretests designed to assess various perceptual characteristics.

The microanalysis of the hand activity was examined first when *S* was adapting to the prism displacement and again during "readaptation." During each of these periods it was the initial two trials, a pair of trials about midway, and the first pair of criterion trials that were microanalyzed. For these trials the exact path of the hand was charted. For the prism adaptation period the mean paths for 19 *S*s are seen in Fig. 2. Four paths are depicted in this figure: Trial 1 (1), the second or third trial (2), the midway trials (M), and the first pair of criterion trials (C). It is clear from Fig. 2 that, on the average, *S*s began by making a large error which on the next microanalyzed trial was altered significantly in the direction of the actual target displacement. By the criterion trials, the initial error was almost entirely overcome.

For the readaptation to zero displacement phase, five trials were microanalyzed, the first three trials and the pair of trials that began criterion. The mean paths for 22 *S*s appear in Fig. 3. Clearly, the initial response is in the direction of the former placement of the target, but by the second microanalyzed trial is essentially back to straight ahead.

More relevant to Warren's paper than the group means are the individual differences revealed by the microanalysis. Fig. 4 shows the group mean path for a midway trial on the initial adaptation condition, as well as the individual paths for three *S*s. It is clear that the individual paths vary markedly. Of interest is the possibility that the differences are related to other perceptual traits. In order to examine this question, *S*s were administered eight pretests which tapped three classes of *S* characteristics. In all, there were 26 submeasures taken from the eight pretests. These pretest data from a total of 48 *S*s were submitted to factor analysis. The varimax rotated factor solution produced nine factors, of which six (accounting for 81.4 percent of the variance) have clear conceptual meaning and were used in further aspects of the analysis. The factors, very briefly, were 1) eye control and accuracy, 2) hand-pointing accuracy, 3) hand-tracking (of a visual target) smoothness, 4) eye-tracking (of the unseen hand) smoothness, 5) right-hand accuracy in reproducing a right-hand position and 6) left-hand accuracy in reproducing a left-hand position. A factor score for each *S* on each of the six factors was calculated by summing his Z-scores for the submeasures that loaded on that factor. These factor scores were used as covariates in a set of stepwise multiple regression analyses, one



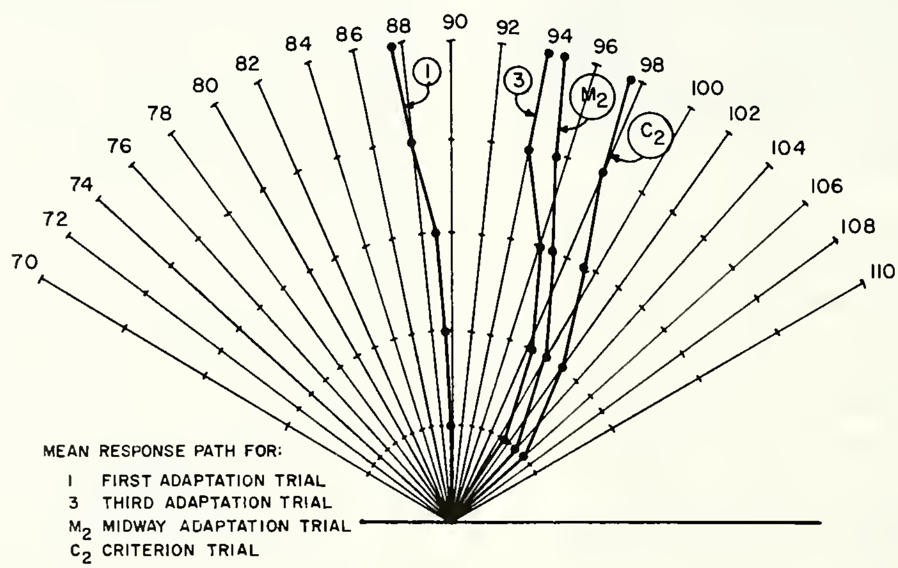


Figure 2. Mean Response Paths for Selected Trials from the 10°-Prism Adaptation Phase. Top Half--Hand Boom Set to *S*'s Left; Bottom Half--Hand Boom Set to S's Right.

analysis for each of several dependent measures. These dependent measures included the number of trials to criterion in both adaptation and "readaptation" phases, the amount of right-hand adaptation, the amount of left-hand adaptation, and the proportion of left-hand shift relative to right-hand adaptation (intermanual transfer).

The results revealed no correlation between the six factors and trials to criterion for either adaptation or "readaptation." On the other hand, the multiple correlation of the factors and amount of right-hand adaptation was 0.52, which is statistically significant. The two factors of eye control and accuracy (15 percent) and hand-tracking (of a visual target) smoothness (9 percent) accounted for most of the variance. Thus, the better the eyes are at fixating or replicating a former position, the more adaptation occurs;

the smoother the hand tracking, the *less* adaptation occurs. In brief, the better the eyes and the worse the hand is, the more adaptation occurs. Conversely, the more the hand can resist the conflicting visual information, the less the adaptation.

Multiple correlation of the factors with left hand adaptation was 0.42, but only one of the 15 pretest submeasures that might on intuitive grounds be relevant to left-hand adaptation showed a statistically significant ($p < 0.05$) correlation.

The last dependent measure, proportion of the right hand adaptation shown by the left hand (intermanual transfer), proved to be multiply correlated 0.76 with the six factors. By far the most important factor here was eye control and accuracy ($r = 0.67$). According to the submeasures of this factor, the worse *S* was at maintaining fixation on a stationary

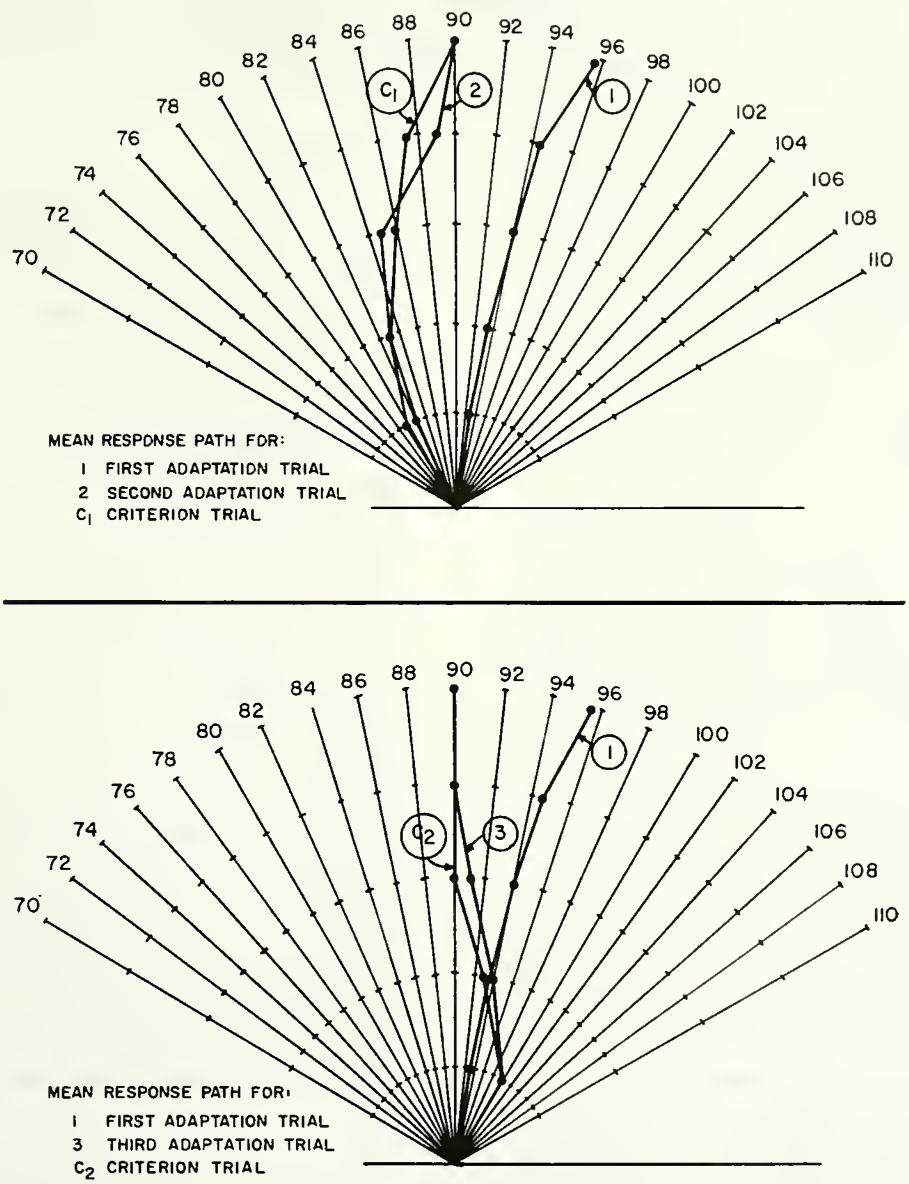


Figure 3. Mean Response Paths for Selected Trials from the Clear-Glass Readaptation Phase. Top Half--Hand Boom Set to *S*'s Left; Bottom Half--Hand Boom Set to *S*'s Right.

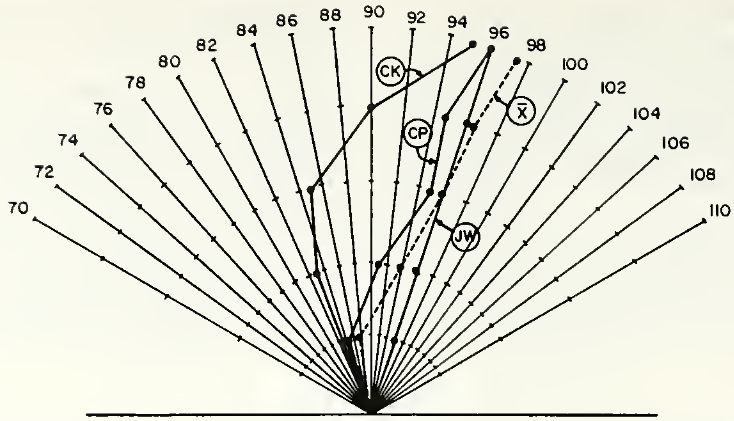


Figure 4. Group Mean Path ($\bar{X}$) and Individual Paths for Three *S*s on a Trial Midway Through the 10°-Prism Adaptation Phase.

target, the more intermanual transfer he revealed ($r = 0.51$). Similarly, the worse *S* was at redirecting his eyes to a previously demonstrated direction of gaze, the more transfer he showed ($r = 0.62$). It is important to note that these relationships are in the direction *opposite* that for the right-hand adaptation measure. Warren's explanation for this apparently anomalous result was that intermanual transfer is the manifestation of a change in *vision* (rather than felt-limb position) and that it is reasonable to assume that the better the eye control the less the visual adaptation and hence the less the transfer. That is, for *S*s with poor eye control most of their ipsilateral adaptation would be visual in nature and all of this visual shift would affect left-hand pointing responses.

Dr. Warren concluded by pointing out that his study, in contrast to most previous ones in this area, was able to account for a significant proportion of the "error variance." This was done by an assessment not of the more global traits, such as "field dependence" (Witkin, 1949), but by means of performance on simple perceptual tasks. Furthermore, certain independent variables (degree of hand control) for future research have been suggested. Finally, this approach to the study of prism adaptation should, in principle, be applicable to most, if not all, complex perceptual phenomena.

DISCUSSION

Because of the pressure of time, the discussion period was cut short. A major point was raised concerning the implicit assumption that the "perceptual traits" measured in the pretests were, in fact, relatively stable *S* characteristics (possibly the result of particular developmental histories). Clearly, since they were measured only once (during the same session as prism-adaptation measures occurred) there is no evidence to support this contention. Furthermore, one of the discussants reported unpublished data of his and several other investigators indicating the lack of a correlation between adaptation to leftward prism displacement and adaptation to rightward displacement, measured a week later. Thus, doubt is cast upon the notion of a trait of "prism adaptability." On the other hand, it was pointed out that the value of Warren's and Platt's findings does not depend upon whether or not such a trait exists. That is, even if a given *S*'s performance on some or all of the pretests were to vary from week to week, the continued presence of the correlations reported in the present paper would justify the use of this research strategy for precisely the reasons which were stated.

The Possible Role of Eye Muscle Potentiation in Several Forms of Prism Adaptation

Sheldon M. Ebenholtz

University of Wisconsin

The "Kohnstamm phenomenon," is the tendency for a stressed muscle to remain innervated for some period of time after issuing the voluntary signal to relax. An example of this effect is seen when one stands close to a wall and presses the back of the hand hard against it; if one then moves some distance from the wall and allows the arm to relax, it will rise involuntarily. The present research was based on the premise that the eye muscles are also subject to this "post-tetanic potentiation," which in this instance may be referred to as "eye muscle potentiation" (EMP). Thus, for example, the continued maintenance of a rightward eye position followed by relaxation of the eye muscle should lead to an *involuntary* drift of the eyes to the right. However, since there is no proprioceptive feedback from the eye muscles, the subject shold incorrectly feel that his eyes are still in the primary position. Several studies (MacDougall, 1903; Park, 1969) have reported just such an EMP effect. Ebenholtz described a successful replication of these results in his own laboratory, using both eye rotation and eye plus head rotation. Similar effects have also been reported by other investigators for atypical eye convergence. Furthermore, if a visual stimulus (a dot of light in an otherwise dark room) is present when EMP is causing the eyes to drift, the stimulus should appear to move in the direction opposite the eye drift. In order to maintain fixation in this event, motor commands must be issued to the eye muscles, serving to *counteract* the EMP. However, according to outflow theory (Festinger, Burnham, Ono, and Bamber, 1967), such centrally monitored commands to the eye muscles should lead to the experience of visual movement (or change of apparent visual locus) in the *same* direction as the eye muscles were "instructed" to move. Ebenholtz reported observing such an effect in several studies in his laboratory. Another prediction stemming from the previous evidence and arguments is that if the eyes are made to *converge* for a period of time and then relaxed, there should be an aftereffect of continued, non-monitored convergence. If subjects are then required to fixate a visual target, they will be forced to overcome the convergence caused by the EMP. Thus, according to outflow theory, this extranormal innervation should cause the target to appear *farther away* than it actually is. Likewise, prolonged divergence should lead to experiencing the target as closer than its true position. These predictions were tested by Ebenholtz (and David Wolfson) in a study which he described in detail. In this experiment, optical devices were used which permitted both level of accommodation and target image size to be held constant. During the pre- and postexposure periods *S* demonstrated the apparent distance of the target by moving his unseen finger away from his body until he felt it to be at the same distance as the visual target. During a 6-minute convergence (exposure) period *S* fixated a luminous target which was set to produce either near-distance convergence (16.47°) or far-distance convergence (6.37°). For both groups the distance of the target during the pre- and posttests was intermediate to these two positions.

The results supported the predictions, in that near fixation led to postexposure overestimation of the target distance, whereas far fixation produced underestimation. In other studies, exposure periods of 2-, 3-, and 4-minute duration proved insufficient to produce these visual effects.

Dr. Ebenholtz went on to point out that adaptation to prism displacement has in some cases been found to be due to a change in registered eye position (Craske, 1967; Kalil and Freedman, 1966). Thus, it is reasonable to ask if these shifts are instances of EMP and if EMP effects underlie prism adaptation. Thus, for example, one can assume that during a prolonged period of prism exposure the position of the eyes would, on the average, be turned in the direction of the prism apex (the direction in which the objective straight ahead has been optically displaced).

A second experiment was designed to investigate this hypothesis, using optical displacement in the *distance* dimension, effected by the use of a pair of base-out wedge prisms, which cause the visual field to appear *closer* than it really is. Prism strengths of 0, 6, 8, or 10 diopters were used. During the exposure period *S*s walked around in a hallway for 15 minutes, not being allowed to see their bodies. The same measure of the apparent distance of a target was used here (during the pre- and post-tests) as in the first experiment. Two target distances, 30 cm and 40 cm, were used during these tests.

The results indicated the presence of a visual aftereffect for all but the 0-diopter group. This is, upon removal of the prism spectacles the visual target appeared *farther away* than it actually was for the three groups whose vision had been optically foreshortened. There was no difference in the amount of adaptation manifested by the 6-, 8-, and 10-diopter groups.

A follow-up study demonstrated that the prism adaptive change was not in the arm (proprioceptive) since prism exposure did not lead *S*s to misreach for a remembered 1-foot distance in the dark, while at the same time the estimate of a 1-foot *visual* distance was affected. Thus, the adaptive component was visual, not proprioceptive.

Also measured in the main study was the potential decay of the aftereffects during a 30-minute period subsequent to the removal of the prisms. Decay occurred in all cases and was found to reach asymptote after 10 to 15 minutes. Remarkably, asymptote was *above* the pre-adaptation levels, suggesting that if *S* remained in the dark, adaptation would persist indefinitely. Furthermore, the asymptote was somewhat higher for the higher prism strengths. Future studies will examine the EMP decay process in more detail.

According to Ebenholtz, the most important implications of his studies bear on our understanding of the prism-adaptive state. If theories which argue for the existence of a truly visual form of adaptation are to be maintained, efforts will have to be made to exclude the possibility of EMP. On the other hand, it may be the case that the visual aftereffects of most if not all previous prism adaptation studies can be explained entirely in terms of this oculomotor phenomenon. Ebenholtz emphasized the fact that the proposed component of prism adaptation does *not* represent a *recalibration*, but merely the visual outcome of an attempt to overcome a load which has been placed on the eye muscles.

DISCUSSION

A major point raised was that, according to Dr. Ebenholtz, the presence of an actual rearrangement of the visual field (or even the presence of any visual field at all) should be irrelevant for the type of adaptation being proposed since all that is necessary is the continued placement of the eye in a particular position, such as off to one side. Conversely, if *S* is exposed to a prism-displaced visual field in which a fixation target is made to *appear* straight ahead, no visual adaptation should result, since *S* is holding his eyes in a symmetric, straight-ahead position. Dr. Ebenholtz agreed with both of these points. Another discussant suggested that Dr. Ebenholtz's evidence that EMP is operative in the "normal" prism adaptation situation is merely circumstantial. Ebenholtz's reponse to this suggestion was that if the effects of, say, prism adaptation are not discernible from those found when *S* merely holds his eyes to one side, and if the variables

that affect prism adaptation also affect EMP in the same way, then one can conclude that at least the visual component of prism adaptation and eye muscle potentiation effects are one and the same.

Motor Transformation Learning

John C. Hay

University of Wisconsin, Milwaukee

When a person turns his head or eyes to one side, the visual field remains apparently stationary despite the fact that the image is sweeping across the retina in the opposite direction. This "constancy of visual position" clearly requires some sort of mechanism by which muscular activity of the head and/or eyes is correlated with the visual input ("reafference") which it produces. Stated differently, when a person moves his head, say to the left, he "expects," possibly from past experience, to see a particular form of optical motion, to the right, and, under normal circumstances, this expectation is confirmed. Stratton (1896), Kohler (1964), and others have found that the initial loss of visual position constancy that human beings experience when exposed to optical inversion or right-left reversal is soon overcome. Thus, it is clear that human beings are capable of modifying the efferent-reafferent correlations necessary for position constancy. This suggests (but does not prove) that the *normal* relations between motor activity and its visual consequences are acquired by the human neonate in the process of making movements and observing the resulting optical motion.

Hay's research involves the use of a rather novel form of recombination procedure to examine the "rules" underlying these efferent-reafferent correlations. His central thesis is that organisms learn not the particular stimuli associated with motor activity, but the *transformations* imposed on stimuli by the motor activity. These transformations must be rule following, rather than requiring a listing of every possible stimulus and its transform. Furthermore, it is not necessary that the input to the "correlation memory" be the result of kinesthetic feedback from motor activity; it may also come directly from the output of the central motor areas, regardless if this output eventuates in a motor response.

In Hay's recombination procedure, a movement of *S*'s head caused a spot of light in an otherwise dark room to move by an amount and in a direction determined by a small, on-line computer (PDP 8/L). Thus, the computer calculated a particular optical transformation from the head-movement signal and displayed it in the form of the spot on a cathode-ray oscilloscope. In most of the experiments reported by Hay, the rules of transformation were either 1) head up, spot right; head down, spot left or 2) head-up, spot left; head down, spot right. Typically, half of the *S*s in an experiment were exposed to 1) and half to 2). The initial response to this situation is to see the light moving from side to side as *S* nods his head. However, after as little as 30 seconds *S* perceives less of the lateral movement, which means that adaptation is occurring and that visual position constancy is being regained.

In the first experiment described, Hay attempted to see if *S*s can adapt

to a constant transformation between head nodding and optical motion when there is simultaneously present a *random* (up-down and/or right-left) movement of light. This situation is comparable to the "real world," in which an organism is exposed not only to reafference but to optical motion from other objects in the environment. This latter motion, which is independent of the organism's own bodily movements, is referred to as "exafference."

With 72 *S*s Hay found, after a 6-minute exposure period, just as much adaptation to the optical transformation in this situation with simultaneous exafference as in a condition in which no exafference was present. That is, after the exposure period, when *S* was tested on the transformation alone, position constancy adaptation was demonstrated, indicating that the random exafference had not interfered with the adaptive process.

In a second experiment exafference was introduced into the transformation exposure in terms of a variable *lag of time* between head nod and optical motion. This, too, is analogous to situations in everyday life, such as the case in which the optical motion of an arm movement does not begin as soon as usual because the hand has been unexpectedly loaded by some weight. In the current experiment the time lag varied from 4 to 225 msec, with a mean value of 118 msec. The only group to show adaptation in this experiment was the one in which the pre- and posttests were taken with a delay of 118 msec.

According to Hay's model, if the situation is such that *S* decides to issue motor commands but then fails to execute them, the expected visual transformation will be *imagined*. Dr. Hay reported a preliminary study in which *S* was asked to count "in his head" the stoplights that he passes every day when going to work. He was required to press a lever as soon as he thought of a stoplight. The prediction was that the time between lever presses would be linearly related to the true physical distance between the stoplights. Tentatively, this hypothesis was supported by Dr. Hay's data. He argued that *S* accesses target items by employing covert motor activity.

In another preliminary study *S* was confronted with a 4 X 4 matrix while a spot of light appeared in a random sequence in each of the squares. As the spot appeared, a number for that cell was called off by *E*. After repeated practice, *S* learned the appropriate number for each cell. Subsequent to these learning trials *S* was asked various questions, such as "What is the sum of column 3?" or "What is the difference between the sums of column 1 and row 3?" For half of the *S*s these questions were asked when the matrix was physically present, including the numbers (stimulus condition); for the remainder of the *S*s the matrix was present but there were no numbers in it (memory condition). The results indicated that the time required to answer various questions varied as a function of the amount of arithmetic computation required but was always less in the stimulus condition than in the memory condition (by about 2.25 seconds). More importantly, however, the reaction time *profiles* over the various questions for the two conditions were nearly identical. Thus, it appears that either eye movements or remembered eye movements are used to access the memory of the visual targets. This, then, is analogous to sending efferent impulses to the "correlator" and accessing the expected visual transformation.

DISCUSSION

Many comments were elicted throughout this presentation. A number of questions, however, involved the need for clarification, probably due to the large number of studies which were described.

The "matrix experiment" seemed to be of most interest. One question asked was if the results of this study implied that everyone has good visual imagery. Hay responded by saying that he did find differences between people who said that they have good visual imagery and those who said that they do not. In particular, poor visualizers reported the need to make overt eye movements over the empty

matrix (the memory condition) while good visualizers said that they did best on the task if they avoided making such movements. Apparently, there was no difference in mean reaction times for these two types of *S*. One discussant asked if it had actually been necessary in the original learning trials of the "matrix experiment" that the cells of the matrix be presented to *S* in a rigid (although random) order. Hay implied that this was not actually necessary. What is important for his model is that the time for a visual search (stimulus condition) be proportional to the time for a memory search (memory condition). It was not expected (and not observed) that *S* would recapitulate the sequence in which the cells were originally presented. Rather, *S* was expected to move the eyes in whatever way he wished in either condition and was also allowed to use "short cuts."

Proposals for the Study of Adaptation to Anomalous Causal Schemata

Ian P. Howard

York University

This presentation consisted of two parts. Howard began by discussing briefly some recent (in press) research on prism adaptation and then concluded with a presentation of a number of research ideas in the area of perceptual-motor schemata which he planned to implement in the near future.

In the first prism adaptation study described, the issue was "What is it that adapts?" *S* was adapted by pointing at a target repeatedly while the visual image was *gradually* displaced to one side, by means of rotary prisms, until a total displacement of 16° was achieved. This "prism-shaping technique" precludes *S* from becoming conscious of the optical rearrangement. At regular intervals throughout the adaptation period *S* was tested on various capacities: 1) pointing at a target with the prism-exposed hand, 2) pointing at a target with the non-exposed hand, 3) pointing at the (unseen) big toe with the prism-exposed hand, and 4) directing the eyes toward the (unseen) toe. In none of these tests was visual feedback provided. Thus, *S* was measured on 1) adaptation in the ipsilateral arm, 2) potential intermanual transfer, 3) felt limb position, and 4) felt direction of gaze, respectively.

It was found that for 9 (out of 22) *S*s there was both a shift in felt limb position and a change in direction of gaze and that the two components summed to the total corrective target-pointing response of the prism-exposed limb. Furthermore, intermanual transfer occurred only for these latter *S*s, and it was equal in magnitude to the change in vision. For the remaining *S*s only felt limb position was modified and its magnitude was less than the total prism-corrective pointing response. Thus, Howard provided convincing evidence that prism adaptation, at least for some *S*s, consists of visual and proprioceptive components that combine additively.

In the second prism adaptation study the aim was to test the hypothesis that prism adaptation will exist

as a change (recalibration) in that part of the body that was active during prism exposure. Howard had *S* wear a long extension on his nose, with a light on the end of it. *S*'s right index finger also had a light attached to it. In the dark and wearing prism goggles *S* either pointed to his stationary "nose light" with his right or left index finger, or pointed to his stationary right or left index finger with his extended nose. Because of the optical rearrangement he initially made errors, which he was allowed to see immediately after each response had been completed. As a consequence of this feedback, *S* eventually was able to make the response accurately.

Based on the previously stated hypothesis, Howard predicted that *S*s who pointed with the hand should reveal a prism-induced change in the felt position of that limb, while *S*s who pointed with the "nose" should experience a change in felt head position. The results were, however, in exactly the opposite direction as predicted. Dr. Howard argued that this finding actually makes sense. That is, a stationary limb undergoes sensory adaptation which makes its felt position more variable (less precise), and there is evidence (from his laboratory and others) that the less acute a system the more adaptable it is.

The last half of the talk was devoted to a discussion of a program of studies just begun, aimed at an investigation of people's generative perceptual schemata (cognitive structures, assumptions, etc.). Schemata are assumptions about the nature of the world which people hold and typically never question. Often, one is unaware that he holds these assumptions unless they suddenly fail or lead to contradictory experience. The "phantom limb" experience is a good example of a situation in which the existence of a schema (body position) is not revealed until its fit with reality slips (an arm is removed). Thus, the "recombination procedure" may be used as a means of revealing the existence and nature of schemata.

Piaget has carried out well-known studies of the development of schemata in children. He showed, for example, that the principle of conservation is generally absent in young children. Only after the age of about six years are children able to see that pouring water from a short, wide container into a long, narrow container does not lead to a change in total volume. According to Piaget, one acquires conservation and other schemata relatively early in life, continues to hold them as an adult, and is able to generalize them to new situations. However, Howard said that he believes, unlike Piaget, that adults can be like young children with respect to situations with which they are unfamiliar. As evidence for this position, Howard gave a demonstration of a common faulty schema in adults. If a continuous loop of string is held in the form of a square and then changed to a rectangle, most adults, when asked, will say that the total area within the loop has remained unchanged. As the rectangle is made narrower they will continue to hold to this conservation of area until it becomes quite obvious that the area is, in fact, diminishing to zero. Another common incorrect adult schema is that an object falling vertically will reach the ground before an object shot horizontally, as from a gun.

Thus, according to Howard, it appears that rather than postulating the existence of *developmental stages* in cognitive growth one must look for the kinds of experience which lead children (and adults) to acquire or unlearn their schemata.

Various kinds of recombination procedure can be used to reveal, modify, and reinforce a person's schemata. In one such procedure Howard has investigated the schema people generally hold with respect to the acceleration of falling objects. *S* is confronted with a vertical screen having three small windows located 1, 2, and 3 feet below the top. He is asked to hold an iron ring at the top of the screen, directly behind it (and thus not visible to him). He is to release the ring and watch it pass by each of the three windows. His experience, typically, is one of surprise, as the ring seems to appear in the lower windows sooner than expected.

A variation of this technique is to arrange the situation so that the falling ring is stopped (by a ledge) and a second ring is made to fall past

the window at whatever latency *E* desires. Thus, *E* can vary the apparent falling acceleration. By asking *S* when the arrival of the ring at the various windows "looks right" it is possible to measure precisely the nature of *S*'s schema.

In a preliminary study described by Howard, *S* was trained to stable, accurate performance at catching the falling ring with a rod at the one-foot distance. Then *S*'s attempts were measured at the 2- and 3-foot windows, with the ring actually stopped by *E* after passing the first window. *S*'s errors again served to reveal his incorrect schema (an underestimation of gravitational acceleration). In a further study *S* was tested (no knowledge of results) on an 8-oz ring and on a ring of half the weight dropping through the same height. It was found that most *S*s behave as if they assume that the fall time decreases by a factor of about $\sqrt{2}$ for a halving of weight. This is the function that follows from the (incorrect) assumption that acceleration is proportional to force (weight).

Thus, the preceding techniques allow for the measurement of schemata. More important, perhaps is the fact that by *confronting S* with the incorrectness of his schema (by allowing him to reach for the falling ring at the second and third windows) it may be possible to correct them. A number of training techniques for this purpose were suggested. An example described by Howard is one in which two identical self-energized toy cars are run, either singly or linked in pairs, under a horizontal screen to emerge at the far side. *S* must anticipate the time of emergence of single and linked cars. The appropriate schema for success at this task is that linking the cars (doubling the weight) does not affect their speed. Most adult *S*s would probably see this immediately and might then be able to apply the principle to the falling-ring situation.

It would, of course, be possible to reinforce incorrect schemata. For example, *E* could catch the falling ring and then let another one fall in such a manner that *S*'s (incorrect) expectation of the time of appearance was confirmed, allowing him to be accurate from the very start in his attempts to catch the ring.

The presentation was concluded with some suggested reasons for common incorrect schemata held by adults. For example, the pre-Galilean assumption that heavy objects fall faster than light objects might represent a generalization from the fact that heavy objects in a *viscous fluid* do fall faster. Similarly, the force with which a spring in a pinball machine is loaded *is* proportional to the speed with which the ball travels.

DISCUSSION

Several discussants pointed out that the assumptions (correct or incorrect) held by most individuals are undoubtedly the result of previous interactions with the world. Thus, for most people, experience has taught that heavy objects *do* fall faster than light objects (due to air resistance). Thus, the "real world" is much "dirtier" than the idealized world of the physicist, and maybe we should be studying "dirty schemata." Howard apparently had no quarrel with this as being a worthwhile topic of study, but nevertheless felt that it is useful to know what people's schemata *are* and to see if these schemata can be modified by experience and specific training techniques.

The Effect of *S*'s Interpretation of "Straight Ahead" Upon Measures of Prism Adaptation

Charles S. Harris

Bell Laboratories

Two commonly used prism-adaptive measures are the pre-post shifts in pointing straight ahead with eyes shut and reporting where the visual straight ahead appears to be located. The first is considered to be a measure of change in felt limb position and the second a measure of visual shift. Harris pointed out that when *S* is viewing a *structured* environment, one that includes walls and other rectilinear objects, *E*'s command to point (or look) straight ahead can have either of two meanings to *S*. On the one hand, *S* may assume that *E* is asking that he point (or look) *straight ahead of his body*. It is, in fact, this interpretation that all *E*s assume (or hope) *S* is making. On the other hand, *S* may interpret the command to mean that he is to point (or look) in a direction that is in line with the walls of the room (or toward the center of the wall which he is facing). If *S*'s vision is undistorted and he has been seated in line with the sides of the testing room and/or the sides of the table in front of him, his behavior of pointing (or looking) straight ahead will be the same, regardless of which assumption he holds. However, if prism goggles are placed on his head, the nature of his assumption can have an important bearing on his response. If the structured visual field is prismatically displaced to one side, *S* will have the same visual experience as he would if he were sitting at a slant with reference to the sides of the room. If in this situation he interprets "straight ahead" to mean a point in line with his mid-saggital plane (as *E* assumes), then (at least initially) he should continue to look (or point) in the same direction as before the prisms were placed in front of his eyes. On the other hand, if he uses the visual framework as his basis for judgments of straight ahead, two things will happen. First, *S* will *immediately* report a new position for straight ahead, one that is in line with the apparent orientation of the visual field. Because *E*s have tended to assume that *S*s were responding in terms of the mid-saggital plane, this change has been incorrectly interpreted as an immediate visual shift. Secondly, if *S* were then to close his eyes and point straight ahead, he would probably point in the remembered direction of the visual axes of the room. This change in arm placement (as compared to the pre-exposure responses) will appear to *E* to be an *anti*-adaptive shift in felt limb position. Harris mentioned a number of studies (some from his own laboratory) which have reported either an "immediate correction effect" (Rock, Goldberg and Mack, 1966) or maladaptive reaching responses (McLaughlin, Rifkin and Webster, 1966).

The point is that what appear to be immediate prism-induced changes in vision and/or proprioception may be only the manifestation of *S*'s interpretation of the concept of "straight ahead." As such, these changes are both trivial (if one is interested in perceptual modification) and misleading. Harris pointed out that in the research of Singer (this conference) *S*s whose visual fields were optically tilted responded to the command to indicate the apparent vertical by showing an "immediate correction effect." However, with eyes shut and asked to set a rod to kinesthetic vertical they placed the rod at a tilt that, if indicative of perception, would represent a maladaptive shift in kinesthesis. It appears likely, then, that here too *S* was using the visual framework, rather than his body, as the basis for his judgments and that what looked like changes in perception were not.

Now it is likely that many *S*s if tested in a structured field will make their judgments of straight ahead in terms of a *compromise* between the two contrasting interpretations. Furthermore, if the exposure period continues for some time (and involves active visuomotor behavior along with visual feedback), "real" adaptation would occur, which will tend to augment (or replace) the spurious change in visual straight ahead. Likewise, the apparent maladaptive shift in pointing straight ahead might be negated, leaving what appears to be the total absence of proprioceptive adaptation.

Because Harris' entire argument is based on the assumption that *S* is using a structured visual frame of reference to determine (or strongly influence) his judgment of straight ahead, the obvious precaution is to omit such a field. This is easier said than done. Even if a dark room is used, *S* is likely to be able to see the testing apparatus during the exposure period, and if the apparatus is rectilinear it may have the undesired effect on judgments of straight ahead. Of course, if the testing apparatus is designed to present a curved array (Uhlarik, 1972), the problem is reduced. Nevertheless, one still must be wary of the possibility that *S* may remember how the testing room appeared from when he first entered it and that this memory may influence his judgments. As a means of avoiding the latter possibility, Harris suggested the procedure of leading *S* into the room blindfolded, having him set in a chair, and then slowly rotating him into position for testing.

DISCUSSION

In the brief discussion that followed Harris' talk, questions centered on whether or not he thought that asking *S* to look or point straight ahead could ever be a trustworthy measure of perceptual adaptation. He said that he thought it could if the precautions he described were implemented. Several discussants asked why it was that one couldn't merely instruct *S* on what *E* meant by "straight ahead" and even give him a demonstration and/or pictorial representation. Harris responded that while the use of appropriate instructions seems to be an obvious solution it will probably fail in many cases, since *S*s do not generally seem able to switch consciously from one assumption to the other.

Speculations on a Model of Prism Adaptation

Robert B. Welch

University of Kansas

Welch gave a short presentation of some ideas and data of his which suggest that adaptation to prism-displaced vision entails, at least in some situations, three different components.

If *S* points at a prismatically displaced target he 1.) experiences a discrepancy between felt and seen position of the limb and 2.) makes target-pointing errors. If, on the other hand, *S* views his optically displaced and actively moving limb in the absence of a target, then the only cue to the presence of the rearrangement is the discrepancy between seen and felt limb position (a discrepancy which may exist even if limb movement is passive, but is probably more salient with active movement).

The behavioral measure of prism adaptation in most experiments is the pre-post shift in target-pointing accuracy without optical displacement or visual feedback. This is referred to as the "negative aftereffect" (NA). However, several investigators (Harris, 1965; Wilkinson, 1971) have argued that NA is actually the sum (or product) of several different components. Welch went on to describe a proposed multi-component model of prism adaptation entailing three different components: 1.) a change in felt limb position, or "proprioceptive shift" (PS), 2.) a change in vision, or "visual shift" (VS), and 3.) a prism-corrective motor response, or a "rule for reaching" (RR).

Welch suggested that the stimulus for PS was the conflict (direct or indirect) between felt and seen limb position. VS may result from an asymmetry of the visual field (the "immediate correction" effect), from very well-practiced, prism-corrective visuomotor responding, or from the automatization of an asymmetric eye fixation response. Finally, although the RR component can be elicited by non-active prism exposure (Howard, Craske, and Templeton, 1965) or concurrent exposure without a target, the best possible situation is one in which *S* is confronted with a target and exposure is of the terminal variety. In this situation *S* will make several initial target-pointing errors and then, typically, engage in a conscious correction and continue to practice this correction until it becomes "automatic." What is crucial here is that *S* ultimately make the prism-adaptive target-pointing response "without thinking."

Thus, according to this model, NA = PS + VS + RR. That is, the total target-pointing aftereffect is the combined result of feeling that the arm is displaced by a certain amount in the direction of the prism-displacement plus seeing the image of the target displaced toward its objective position plus a rule for correct pointing.

The existence of PS and VS has already been demonstrated by a number of investigators. It is the third component, RR, for which supporting data must be provided. Welch presented some data (mostly unpublished) indicating that when independent measures of PS, VS, and NA are taken from the same *S*s (and the order of postexposure measures is counterbalanced) NA significantly exceeds PS plus VS. Furthermore, the correlation between NA and (PS + VS) is quite low (approximately + 0.35). Both of these findings support, in an indirect way, the existence of a third component. That this derived third-end state of prism adaptation is, in fact, a motor learning component is supported by the fact that when prism exposure does *not* entail a target there is, according to Dr. Welch's data, little or no difference between NA and (VS + PS).

Welch suggested that the proposed motor learning component is more susceptible to "learning variables" (see Taub, this paper) than are the other two components. Evidence for this hypothesis comes from several studies. In one it was found that the RR component occurred when prism-exposure trials were distributed, but not when they were massed. In a second study, it was found that brain-damaged *S*s failed to acquire RR, while non-brain-damaged *S*s did.

A final point made by Welch was that whether or not an investigator will actually be able to measure all three prism-adaptive components may depend upon the nature of the tests used. For example, a slow target-pointing response in the postexposure test should maximize the contribution of the PS component to NA, while a ballistic response should reduce its importance, except for that amount which exists at the *starting position* of the limb.

DISCUSSION

A number of interesting points were raised concerning Welch's proposed three-component model of prism adaptation and the ways in which it should be tested. One discussant said that Hay and Pick (1966) had found that PS + VS = NA in a study in which *S*s wore prism spectacles continuously for 42 days. Welch agreed that this appeared to be contradictory to his notion that a third prism-adaptive component exists. Several people mentioned the fact that since decay of prism adaptation seems to be rather slight, at least for 10 to 15 minutes after the adaptation period, it may be that the procedure of counterbalancing the order of postexposure measures is not necessary. On this same line another discussant argued that the best solution would be simply to measure *S* on only *one* of the types of adaptation. Welch agreed that this would solve the problems of 1.) potential decay of prism adaptation, 2.) potential differential decay of the various components, and 3.) obtaining the precise measure of the absolute magnitude of each component. A distinction was raised by one of the discussants between 1.) the efferent (motor learning component) proposed by Welch, and 2.) the efferent sense of body position postulated by Taub (this conference) with respect to his deafferented *S*s. The latter is not what Welch was talking about. In defense of a three-component model, one of the discussants argued that even if the sum of PS and VS is found to equal NA, there might still be a third component since it is not clear that the measures of PS and VS can actually be independent of each other. That is, it is possible that the individual measures of VS and PS may be *overestimates* of their effects during the total visuomotor response used as a measure of NA. If that is true, then when the sum of PS and VS equals NA, it really means that a third component (RR) is present.

Past, Present, and Future of the Recombination Procedure

Ivo Kohler

University of Innsbruck

The closing address of the conference was designed to review the origins of the use of recombination procedures, to tie together, or at least comment upon, the previous talks, and to suggest the directions in which future research will go.

Kohler began by acknowledging a debt to the pioneering studies of optical inversion by Stratton (1896), not just in terms of his findings but because of his conscious attempt to restrict as little as possible the range of relevant observations. The technique of having *S* wear distorting spectacles for prolonged periods of time in a "real life" environment while reporting all relevant perceptual and perceptual-motor experiences was the basis of the famous "Innsbruck studies" by Kohler (and Erismann). Such an "openness" led to the discovery of the "situational aftereffect." An example of this phenomenon is the finding that after wearing spectacles with left halves blue and right halves yellow, *S* comes to experience a complementary color aftereffect with spectacles removed, which is *contingent upon the direction in which he looks.* Analogous findings have been reported more recently (McCollough, 1965; Hajos, 1970). He argued that much of our everyday experience may involve various contingent-produced visual perceptions the existence of which only become apparent with optical rearrangement. For example, if the visual field is inverted, falling objects seem to move much faster than if seen to fall with vision normal. Evidently, the experience of the apparent speed of objects depends (is contingent) upon the direction (up vs. down) in which they move. Another example is the fact that the perception of facial expression is drastically altered if the face is seen upside down.

One of the problems encountered by Kohler (and Erismann) is the fact that lenses used for tilting or inverting the field also constrict the size of the field. Two ways for overcoming this problem were devised. One involved the use of mirrors, since they can be made as large as desired. For example, if a mirror is worn like the brim of a hat and *S* looks up into it, he will see the floor and his body inverted. The disadvantage here is the fact that *S* must place his eyes in an atypical position. A second technique for providing *S* with a large rearranged field is to build an environment (such as a small room) and then tilt or even invert it.

Kohler discussed several unpublished studies using the recombination procedure. In one study a *S* wore prism goggles for eight days while engaging in everyday activities. At the end of the 8-day period he was requested to directly face a wall. It was found that *S* could comply quite accurately with this request, suggesting that he had adapted visually to the prismatically induced rotation of the fronto-parallel plane. However, when he was asked to face straight ahead with eyes shut, it was seen that he held his head off to one side relative to the rest of his body. Thus, this result supports a much later suggestion of Harris (1965) that what at first seems to be an example of visual change may actually be a manifestation of a change in felt eye and/or head position.

The great interest in adaptation to rearranged vision that has existed in the United States since the research of Held (1955), was attributed not only to Kohler and Erismann's work but, more importantly, to the ideas of Holst and Mittelstadt (1950). Americans have been particularly interested

in breaking down adaptation into its various components, as has been seen in several of the talks at this conference. This, however, is a difficult task, since these components are probably not independent of each other.

Kohler commented briefly on each of the previous talks. He suggested that with respect to Taub's paper, the finding of 100 percent adaptation in deafferented monkeys might be interpreted in terms of an increase in the length of the feedback loop. Thus, feedback in the deafferented monkeys may have been *delayed*, and it is well known that delayed feedback circuits are accompanied by an increasing instability (and therefore adaptability) of the system.

Kohler disagreed with the criterion used by Singer to distinguish sensory spatial adaptation (SSA) from behavioral compensation (BC). It will be recalled that the distinction was made partly in terms of the longevity of the aftereffects--those due to SSA decaying in 2 to 3 minutes, while BC lasts much longer. He pointed out the existence of very long-lasting aftereffects that, nevertheless, appear to be examples of SSA, because they result from passive observation of unchanging stimulation; an example is the "McCollough effect."

Kohler was very interested in the study described by Uhlarik because he had done an unpublished study himself many years ago in which *S*s walked around while viewing a visual field that was undergoing constant (and quite rapid) change due to counter-rotating prisms. Unfortunately, *S*s became so nauseated that the study had to be discontinued before any interpretable data could be gathered.

Referring to Warren's presentation, he said that he was very impressed with the general technique of "microanalysis." There are a few previous studies (Eysenck, Granger, and Brengelmann, 1957) of individual differences, but typically they used "abnormal" *S*s (e.g., neurotic, schizophrenic). Kohler also referred to a study in which the perceptual traits of blind individuals were correlated with their ability to move around without bumping into objects. It was found that people who were very good at avoiding obstacles were also quite sensitive to differences in the timbre of sounds (echoes).

In response to Ebenholtz's talk, he asked how eye muscle potentiation could explain the adaptation that has been demonstrated for split-field prism goggles (Kohler, 1964). That is, in the case of adaptation to spectacles which displace the upper half of the field but not the lower half, it does not seem possible to invoke eye muscle potentiation since the latter implies an all-or-none state. Rather, it seems necessary to assume that adaptation to split-field prism spectacles is gaze contingent.

Kohler related two observations from his laboratory that were similar to several of the studies which Hay described in his presentation. In one it was observed that if *S* wears wedge prisms and moves toward a fixation point straight ahead, the point will appear to move laterally toward the prism base. However, after a few days this illusory movement will disappear. If the goggles are then removed, the fixation point will again appear to move, but now in the direction of the prism apex. A second, related observation is the case of a person accustomed to wearing eye glasses. If the lenses are removed from the frames and the person moves these empty frames about while looking through them, a fixation point will appear to move. However, this will not happen if someone else moves the frames in front of the person's eyes. In both the prism-wearing and lenseless-spectacles situations, persons acquired a constancy of visual position as the result of prolonged experience with a particular transformation. When the prism goggles or spectacle lenses were removed, this constancy was no longer appropriate and, hence, resulted in aftereffects.

In response to Howard's discussion of causal schemata, Kohler described some observations that he had made of the experienced acceleration of falling objects in an *inverted* visual field. If one is confronted with a room that is truly upside down but which appears, because of roof prisms, to be rightside up, objects will be seen to "fall" toward the

ceiling. Furthermore, the acceleration of these objects will be perceived as much greater than in the case of objects that are falling, as they are supposed to, toward the floor. Kohler concluded that we may underestimate acceleration to which we are adapted (as Howard showed) and overestimate acceleration that is atypical.

Finally, Kohler spoke of his views with respect to the future of the recombination procedure. One of the aims of future perceptual research, he believes, is to come to an understanding of how the central nervous system processes, simplifies, or otherwise makes sense out of the myriad of stimuli bombarding the sensory receptors, usually from several different modalities at the same time. There is an increasing tendency for psychologists (and others) to view the brain as an exceedingly complex computer, one which has evolved to its present state in man as a result of a series of successes and failures to meet the demands of the environment. It is possible to examine the nature of the "analyzers" by means of physiological techniques (Hubel and Weisel, 1959) or by inference from behavioral measures, as seen in the research on "backward masking" (Gilinsky, 1967).

The recombination procedure may lead to a further understanding of the perceptual analyzers whenever it is found that some sorts of rearrangements are easier to adapt to than others. For example, the failure to find any adaptation whatsoever to a particular form of optical rearrangement would undoubtedly have implications for the nature of the perceptual analyzers involved.

Kohler concluded by saying that he believes that two important lines of future research in the area of recombination are an examination of "contingent adaptations" (of which he spoke earlier), and an examination of how the nervous system responds to the sensory invariances that demonstrably exist on the receptor organs (Gibson, 1966).

REFERENCES

Craske, B. Adaptation to prisms. Change in internally registered eye position. *British Journal of Psychology*, 1967, 58, 329-35.

Eysenck, H. J., Granger, G. W., & Brengelman, J. C. *Perceptual processes and mental illness.* New York: Basic Books, 1957.

Festinger, L., Burnham, C. A., Ono, H., & Bamber, D. Efference and the conscious experience of perception. *Journal of Experimental Psychology Monograph*, 1967, 74 (4, Whole NO. 637).

Freedman, S. J. (Ed.) *The neuropsychology of spatially oriented behavior.* Homewood, Ill.: Dorsey Press, 1968.

Gibson, J. J. *The senses considered as perceptual systems.* Boston: Houghton Mifflin Co., 1966.

Gilinsky, A. S. Masking of contour-detectors in the human visual system. *Psychonomic Science*, 1967, 8, 395-96.

Harris, C. S. Perceptual adaptation to inverted, reversed, and displaced vision. *Psychological Review*, 1965, 72, 419-44.

Hajos, A. Sinnespsychologische Untersuchungen zur Invarianzbildung im visuellen System des Menschen. Paper read at Kybernetik-Kongress, Berlin, March, 1970.

Hay, J. C., & Pick, H. L., Jr. Visual and proprioceptive adaptation to optical displacement of the visual stimulus. *Journal of Experimental Psychology*, 1966, 71, 150-58.

Heinemann, E. G. Figural after-effects in kinesthesis: Effects of object width and repeated presentations. *Journal of Experimental Psychology*, 1961, 61, 51-56.

Held, R. Shifts in binaural localization after prolonged exposures to atypical combinations of stimuli. *American Journal of Psychology*, 1955, 68, 526-48.

Held, R., & Freedman, S. J. Plasticity in human sensorimotor control. *Science*, 1963, 142, 455-62.

Held, R., & Hein, A. Adaptation to disarranged hand-eye coordination contingent upon reafferent stimulation. *Perceptual and Motor Skills*, 1958, 8, 87-90.

Holst, E. von, & Mittelstadt, H. Das Reafferenzprinzip. *Naturwissenschaften*, 1950, 37, 464-76.

Howard, I. P., Craske, B., & Templeton, W. B. Visuo-motor adaptation to discordant ex-afferent stimulation. *Journal of Experimental Psychology*, 1965, 70, 189-91.

Hubel, D. H., & Wiesel, T. N. Receptive fields of single neurones in the cat's striate cortex. *Journal of Physiology*, 1959, 148, 574-91.

Kalil, R. E., & Freedman, S. J. Persistence of ocular rotation following compensation for displaced vision. *Perceptual and Motor Skills*, 1966, 22, 135-39.

Kohler, I. The formation and transformation of the perceptual world. *Psychological Issues*, 1964, Monograph 12.

Kohler, W., & Wallach, H. Figural after-effects: An investigation of visual processes. *Proceedings of the American Philosophical Society*, 1944, 88, 269-357.

McCollough, C. Color adaptation of edge detectors in the human visual system. *Science*, 1965, 149, 1115-16.

MacDougall, R. The subjective horizon. *Psychological Review Monograph, Supplement*, 1903, 4.

McLaughlin, S. C., Rifkin, K. I., & Webster, R. G. Oculomotor adaptation to wedge prisms with no part of the body seen. *Perception & Psychophysics*, 1966, 1, 452-58.

Park, J. N. Displacement of apparent straight ahead as an aftereffect

of deviation of the eyes from normal position. *Perceptual and Motor Skills*, 1969, 28, 591-597.

Rock, I., Goldberg, J., & Mack, A. Immediate correction and adaptation based on viewing a prismatically displaced scene. *Perception & Psychophysics*, 1966, 1, 351-54.

Stratton, G. M. Some preliminary experiments on vision without inversion of the retinal image. *Psychological Review*, 1896, 3, 341-60, 611-17.

Uhlarik, J. A device for presenting targets and recording positioning responses in one dimension. *Behavior Research Methods and Instrumentation*, 1972, 4, 15-16.

Uhlarik, J. J., & Canon, L. K. Influence of concurrent and terminal exposure conditions on the nature of perceptual adaptation. *Journal of Experimental Psychology*, 1971, 91, 233-39.

Weiss, P. A. Self-differentiation of the basic patterns of coordination. *Comparative Psychology Monograph*, 1941, 17, 1-96.

Wilkinson, D. A. Visual-motor control loop: A linear system? *Journal of Experimental Psychology*, 1971, 89, 250-57.

Witkin, H. A. Perception of body position and the position of the visual field. *Psychological Monograph*, 1949, 63, No. 7.

THE LIGHT PERMEABILITY OF THE RETINA: EXPERIMENTS WITH BLIND, COLOR-BLIND, AND SEEING SUBJECTS*

Johan Weckroth**
Pentti Miettinen**
Eila Weckroth**

The most essential functional characteristic of a sense modality, the eye in particular, is its ability to achieve within enormously varied stimulus and background conditions, an adequate level of habituation and to maintain its sensitivity in both directions. This ability is obviously not based on characteristics of a single receptor-neuron unit, but is achieved by, or is dependent on, interaction between neural units. This dependency has been especially emphasized by Pribram (1971) and also by Glezer, Bertulis, Ivanov, Kostelyanets, and Bodvigin (1971). On the basis of recent results Pribram has also been able to ascertain that in this connection an efferent control mechanism also operates within the visual system (Glezer, et al., 1971, p. 44). On the other hand the Glezer group has emphasized that the interaction may be based on different mechanisms at different retinal levels, thus indirectly stressing the generality of this functional characteristic of the visual system (Hartline, 1940; Hubel & Wiesel, 1962; Ratliff, 1965; Kuffler, 1953; Pribram, 1971, p. 64).

Correspondingly, a predominant anatomical characteristic is a certain duplexity of retinal substrictures which form a *bipolar modal unit* (such as the two responsible for photopic and scotopic vision). On the level of neural events we recognize this bipolarity in concepts such as "excitatory and inhibitory zones of a receptive field," "simple and complex field," "on-off response channels," and, finally, in the most general form at the behavioral level in the reciprocal phenomena of "contrast enchangement" and "adaptation." This bipolarity is further reflected in reference concepts such as "jump," "shift," and "neutral point" when reactions of the eye are illustrated graphically.[1]

Consideration of the eye as a servo system implies that the basic receptor units or their interaction have not always been the same. It further implies that the eye as a part of the brain has been able to develop its receptor system which originated either from a polygenetic or monogenetic initial stage.[2] From the above, it seems logical to assume that the bipartite systems once developed, were apparently founded on some base, a "reference background," "point of support," "pivot" or whatever the name may be for a center around which the bipolar system could be built. As a matter of fact, this type of development seems impossible unless the system can establish or find a "hinge" around which the element can turn.

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**University of Tampere, Finland.

Because we imagine the development on this basis, the choice between monogenetic and polygenetic views naturally influences our concepts regarding the potentialities of the primary elements, and the manner of the development. The difference is perhaps most distinctive with respect to the concept of a "hinge," and its location and characteristics. The simpler postulation of one single primary unit leads even here to a simpler model of thought, so far as it seems reasonable to locate the point of support *outside* of the element. But the differences must not be exaggerated, not even in other respects. The difference between the microanatomical or spectral structures of what we think are basic receptor elements may also be ostensible. Recent analysis of invertebrate retinae by Wasserman (1973) may be of central relevance here. He presents findings against what he calls the "tuned receptor paradigm" by listing examples of invertebrate retinae (crab, crayfish, bee, etc.) which have non-tuned receptors. He actually draws the picture of the basic element perhaps most urgently needed in the development outlined above, when he describes the non-tuned, double peaked, bipolar "beta" cell as being able to "change the relative sensitivity of the two peaks" and states, "that at least some 'alpha' cells are really beta cells which have lost some of their light sensitivity." Since our aim is not to validate either of these views we refer to the discussion at the end of this article, which, in a sense, deals precisely with the question of what is gained with that "loss."

Obviously, even momentary bipolar function needs a base or a neutral point. The "hinge" in turn apparently has its counterpart outside of the eye; being alternately some predictable level of light intensity or adaptation, contrast, color, or the like. So the question arises whether all bipolar functions of the present, and the phylogenetic long-term development of the past could be content with a common base as a point of support. A search for such a structural property led to the assumption that such a property could be an innate characteristic of the background of the eye in cooperation with its own reflectance characteristic and the light permeability of the retina.

Surprisingly little has been said in the literature[3] regarding the permeability of the retina or its connection with the fundus in spite of, say, the "perverted" posture of the receptors, with the pigment epithelia being the last element from the point of view of the source of light. The pigment epithelia actually lie as if their aim were to prevent most free re-flow of light from the background of the eye to the nerve endings and perhaps through the whole retina.

Is the above-mentioned "gain" connected with this turning of the receptor elements? If so, there are losses as well in the form of reduced general sensitivity. Can it be that color perception as an independent entity of sensation would not be possible without this "perverted" posture? Could this base be considered as a "*conditio sine qua non*" for all integrative functions based on neural interaction or dealing with perception of color, just because it is homogeneous and colored? The functions we have in mind are those such as the efferent control mechanism, I - E components of the receptive field, on-off components, etc. And, finally, does this base and turning toward it also form a necessary condition for the development of the subcomponents (by means of genetical selection), i.e. for the differentiation of "alpha" cells, because invertebrate eyes which lack this turning may often also have retina composed of non-tuned, double-peaked receptors, such as the honeybee.

Based on the above, what would happen if light could be conducted directly toward or through the fundus, otherwise bypassing the eye (in vivo). In other words, *what would be the sensation when the receptors of the retina were forced to rely for their orientation exclusively on the light reaching them from the background of the eye.* If perception of something actually exists, what is the direction, shape, and color of the perceived object, and do individual differences exist?

METHOD

The light was directed through the fundus of the eye via the mouth. A round, 12 mm, acrylic plastic rod was used, bent at one end about 90° in order to direct the light upwards. The other end of the rod was fixed to a can which concealed the light source, a normal 45 W incandescent lamp. The rod was painted with strongly reflecting white paint, and then with black paint to hinder light penetration.

The subject was asked to hold the pipe in his mouth so that its open end was directed upwards towards the palate, the mouth closed as tightly as possible. He was instructed to push a button if a change was perceived. At the beginning of the test a 5-10 minute dark adaptation time was required but on retesting only four minutes were necessary.[4] The light was switched on at irregular intervals. A positive reaction was recorded when the subject pushed the button promptly after the flash was switched on, in a sequence of twelve stimuli.[5] The subject was then asked to describe verbally the quality of the change he perceived. If he said he saw a light he was further asked to tell about the quality of the light and about the direction from which it seemed to come.

SUBJECTS

Three groups were used as subjects:

Blind

1. Fourteen subjects diagnosed as blind or as having severe visual impairment were chosen randomly.[6] The search was originally focused on subjects born blind but having presumably intact retina. The extreme rarity of such cases forced us to give up before anyone was found.

Color Blind

2. The first group was comprised of a sample of 12 boys from a nurse's list of 24 pupils in elementary school. The list embraced all pupils having any kind of deviant sign pertaining to color weakness or blindness in an Ishihara test (given by the nurse). Later a replication group were collected from a total group of 115 boys (all from the top form, mean age between 14-15). From this group were selected 18 boys of whom 9 were evidently color blind, 4 evidently non-color blind and the rest unilateral or other problematic cases.

Normal

3. This group was composed of 12 subjects with no sign of color defect. The majority of this group were students or other persons working at the laboratory. Two African students were intentionally included in the group.

RESULTS

Blind Subjects

Diagnostic description of subjects and their reactions to the "light pipe" test are summarized in Table 1.

The term blind is naturally a legal term conditioned by local circumstances. It is, however, a common observation that only a fraction of the group are totally blind; estimations varying between 10 and 30 percent depending dominantly on the criteria applied in determination of the defect. In this orientation trial we were not anxious to keep the group homogeneous with respect to the degree or severity of the blindness or with respect to other relevant characteristics, such as etiology, duration, age at onset, or quality of the blindness. Hence the picture obtained is somewhat inconsistent. With respect to qualitv, however, we hoped to have included subjects with some sort of otherwise verified neural defect, who could give us a hint as to the practical usefulness of the device as a diagnostic instrument.

Along the structural continuum, lens-retina-neural net, the apparatus seems to be most effective as a detector of expressly retinal malformations or lesions. In general, subjects who sense some light from ahead in

TABLE 1

Blind Subjects

N	Age	Sex	Status	Test Reaction
			Totally Blind	
1	19	F	Visual acuity in both eyes--none. Congenital cataract. Retrolental fibroplasia.	None.
8	19	F	Visual acuity in both eyes--none. Congenital cataract. Chronic uveitis.	Sees light coming from the front of the left eye, white light, no changes on the right side.
			Poor Visual Acuity in Both Eyes	
2	32	F	Right eye 0.1, left eye f.c. 2 m. Severe proliferative changes, in the left eye large white mass down. Diabetic proliferating retinopathy. Complicated cataract.	None.
3	24	M	Right eye 0.5., left eye 0.1. Numerous hemorrhages of all sizes; numerous small exudates and swelled veins. Diabetic retinopathy.	None.
6	63	F	Right eye 0.1, left eye f.c. 10 cm. Complicated cataract. Chronic uveitis.	After extended adaptation, sees light coming from the back of the right eye. No changes on the left side.
7	44	M	Right eye 0.4, left eye 0.4. Optic atrophy. Keratitis profunda. Lues.	Sees faint dawn of light dominantly on the right side.
9	20	F	Right eye light projection, left eye 0.05. Both disks pale and atrophical Craniopharyngeoma. Blindness after cranial operation.	Sees faint light on the right side, weaker on the left side.
10	31	M	Right eye f.c. 1 m, left eye f.c. 4 m. In the right eye chronic postoperative uveitis; in the left eye a very large disciform macular degeneration. Retinal detachment in the right eye and myopic degeneration in the left eye.	Sees light on the left-eye side, light is coming from the front above the left eye, sometimes brighter, like rising sun, reddish border. No changes on the right side.

TABLE 1 (Continued)

N	Age	Sex	Status	Test Reaction
11	20	M	Right eye 0.5, left eye f.c. 4 m. Partial atrophy of both disks and nystagmus.	Sees white blots located straight ahead of both eyes.
12	16	F	Right eye f.c. 3 m, left eye f.c. 1 m. Corneal degeneration and chronic uveitis in both eyes after transplantation.	Sees yellow light located above the eyes, sees the light in both eyes but brighter on the left side.
13	18	M	Right eye f.c. 1 m, left eye f.c. 5 m. Severe nystagmus. Congenital cataract. Chronic uveitis.	Sees yellowish light in both eyes, brighter in the right eye.
14	24	M	Right eye f.c. 2 m, left eye f.c. 2 m. Congenital retinal degeneration in both eyes.	Sees light in both eyes, brighter on the right side, upper part brighter, lower part reddish.
			Poor Visual Acuity in One Eye	
4	48	F	Right eye 1.1, left eye f.c. 2 m. Central chorioretinitis.	Sees light on the right side, reddish light, no changes perceived on the left side.
5	68	F	Right eye 1.0, left eye no light projection. Optic atrophy, blindness after cranial operation.	Sees light on the right side coming from above the right eye, no changes perceived on the left side.

their surroundings also sense light coming from behind; that is 70 percent of those who saw at least something from the normal direction reacted to the light coming from behind, whereas only 20 percent of those totally blind reacted to the light from behind. A drastic exception to this rule were retinopathic eyes, of which only 17 percent reacted to the light coming from behind. This unexpected result may lead to a revaluation of the relevant factors listed as causes of blindness.

The syndrome is, in its most extreme form, called *proliferative retinopathy* (Beetham, 1963; Caird & Garrett, 1963; Safir & Rogers, 1970). A characteristic of this syndrome is the development of a pathogenetic tissue and a detachment of the retinal layer from the sclera or from the background of the eye (fundus oculi). On the basis of the results there seems reason to assume that especially in connection with diabetic retinopathy the reduced optical perception or blindness is connected with, if not primarily caused by, the reduced sensitivity of the receptors with regard to reflected light (from behind) which means literally that the receptors have a reduced ability to receive that light. According to this assumption, the actual reducer of the receptor's sensitivity is the pathogenetic tissue, a cement-like nontransparent matter which intrudes between the pigment layer and the sclera, blocking the reflecting light from the receptors. To our knowledge, the question of how this malformation is related to the disturbed metabolic functions of the diabetic is still open. Untouched, for the time being, has also been the above-mentioned possibility that the effect of this tissue as a cause of blindness could actually be based on its property as an obstacle--hindering the reflected light from reaching the receptors. This displacement of the retina, caused by the foreign tissue as such, has presumably hitherto been considered as a self-evident cause of blindness. This displacement may, however, be the necessary but not sufficient condition of blindness. These more clinically loaded questions will, however, be treated elsewhere (Miettinen & Weckroth, in preparation).

There is another trend also indicative of the critical position the truly retinal characteristics have in connection with this test. Both unilateral cases and bilaterally poor-sighted cases (Nos. 4-7 and 11-14 respectively) showed certain lateral differences in their reactions to lightened background, while there were also differences between the eyes with respect to normally directed light. Between these asymmetries there seems to be a trend which implies that reactions to inside light stand in some proportion to reactions to outside lights (discrimination of stimuli). If we may overlook some mixed cases and exaggerate some slight differences, the trend seems to be the reverse in the qualitative subgroups of blindness listed. If the defect is focused just in the retina or "after" it, there seems to be an expected relation between the asymmetries so that the more poor-sighted eye probably lacks the inside reaction or shows damped reaction. On the other hand, when the defect is located anterior to the retina, as a rule, poor sight correlates with brighter reaction, this being obviously due to the dim tissue located between the lens and the retina (the dimness of the lens and vitreous humor).[7]

This type of sounding naturally needs a replication which should prove how far the handicap is actually connected with the non-peremability of the tissue and not caused solely by the displacing effect the growth of the tissue itself has. A replication focused on an analysis of the optical correlates (besides accuracy) associated with early signs of retinopathy would also give hints with respect to the practicability of the device. If the replication confirms the result obtained, its theoretically most interesting implication is that a dim (non-permeable) medium may impair visual accuracy even when it is located *behind the retina*.

Color Blind Subjects

Diagnoses of color-blindness and reactions to the light pipe test are summarized in Table 2.

TABLE 2

Recordings of Reactions and Verbal Reports When Light was Directed Through the Fundus Oculi, and Index Showing Bilateral Asymmetry Between the Eyes in Ishihara Test

Subject	Ishihara Diagnosis	Light Test Number of Correct Reactions	Verbal Report	Lateral Asymmetry Index
1	Deuteranomaly	0	Nothing	3
2	Deuteranomaly	0	Nothing	X*
3	Deuteranomaly	5	Sense vibration as if eyes were opened, light color	9
4	Deuteranopic dichromat	0	Nothing	X
5	Strong deuteranomaly	0	Nothing	4
6	Strong deuteranomaly	0	Nothing	4
7	Protanopic dichromat	12	Dark shape on lighted back-ground	5
8	Deuteranomaly	0	Nothing	4
9	Strong deuteranomaly	12	Yellowish flashes in front above the eyes	1
10	Strong deuteranomaly	12	Round yellowish light on left side	X
11	Monochromat	1	Vertigo, faint light behind the eyes	0
12	Color normal	12	Bright light more on right side, above the eyes	0

*Subjects marked with X could not be contacted for retest.

There was no reason to be suspect beforehand of the Ishihara test as a criterion of color blindness.[8] Confidence was based on the implicit assumption that the light test would be able to make distinctions in every case between protanopes and "others." Obviously, this was a false assumption with respect to the critical class of color blindness. Control measurement of color blindness carried out after all subjects had been tested, revealed that the first subject who gave an entirely positive or normal response was actually the only protanope in the group. The control measurement also revealed that a subject showing no signs of color blindness had mistakenly been included in the group.

The attempt to analyze the reactions of color-blind subjects was based on the assumption that explainable differences occur; if not within the color-blind group, at least between color blind subjects and normal subjects. The trial was motivated particularly by the likelihood that reactions may be lacking entirely, but that this could be explained by reference to the contracted spectral sensitivity curve of the protanopes. Thus, results obtained are paradoxical with regard to the expected results in several respects. First, a remarkable proportion (70 percent of all subjects suffering from deuteranomaly or deuteranopia) did not see any change, that is did not perceive any light. Second, there was a categorial response set observable, as expected, but this ability to see all of the successive stimuli or none at all is annoyingly conspicuous also in the groups of deuterans. In the group of nine deuteran subjects there were two who reacted spontaneously after each stimulus.

Actually, the one distinct exception (No. 3) from the general rule either to see or not to see forced us to inquire into the reliability of the criterion measurement. On the basis of one well-known case of unilateral color-blindness (Graham & Hsia, 1953; Graham & Hsia, 1954), it seemed possible that the exceptional intermediary case might be such a unilateral case. Therefore a retest was performed with the Ishihara test. This time each eye was tested separately (subject covered the other eye gently with his hand).

Ordinary coefficients of reliability were not computed because it soon transpired that the problem of reliability in a group of color-blind subjects is distinctly different from that in a normal group. Instead we restricted ourselves to recording for each individual a *discordance index* indicating the discrepancy between the eyes. Comparison of the mean index of the group with the corresponding mean value of the control group displayed that discrepancies between the eyes were manifold in the color-blind group. The discordance index in the observed group was 4.29 and in a couple of control groups 0.30, N = 10; and 0.13, N = 40.[9] The difference between the means of the color-blind group and respective control groups was highly significant ($t = 5.1$, $P < 0.01$ and $t = 14.7$, $P < 0.01$ respectively). It is evident that the reliability problem (in a sense of parallel-reliability which could be estimated on the basis of two such independent measurements) is entirely different from that of the normal group. Evidently the discrepancy so common in this sample is not merely a problem of decreased reliability. It may be a central problem connected with the structure of the deviancy itself, implying that quantitative differences are not based on identical underlying dimensions in the anomaly group and the anopia group respectively. From a strictly psychometric point of view this implies that the measurement of a color weakness or defect by means of such a test does not have the same meaning in the color-blind group as in the normal group. This structural problem may reflect itself in connection with unilateral cases precisely in that the more deviant eye never fully develops to the degree genetically intended, because of the interaction between the eyes. The indefinite character of such cases is mentioned also by Graham and Hsia (1953, p. 282).

Individual values of the discrepancy index are listed in the last column of Table 2. In harmony with the expectations, the critical case (No. 3) actually gets the largest value. The conclusion seems to be warranted that the subject in question

is a unilateral case whose seemingly high reaction value in the light test can be explained by reference to the normal eye.

This was an additional reason motivating the replication of the experiment. The replication group was treated differently in two respects from the beginning. First, the whole group of top form pupils (N = 115) were tested bilaterally and the sample was picked on the basis of the results obtained separately for both eyes. Second, the final score of the test was arrived at by a somewhat unconventional method in that every response was registered separately for each chart, and one point was given for each correct response. If the correct response was identical with a response given as a rule by color-normal subject on that particular chart, it was designated normal, and correspondingly if it was identical with responses usually given by color-blind subjects it was designated as a color-blind response. Incorrect responses were omitted.

On the basis of all the responses given, a particular *color weakness index* was computed for each subject by subtracting the color-blind responses from the normal responses. On the basis of this index the sample was divided into three subgroups: color-blind, color-weak, and color-normal; one strongly normal case was moved from the middle group to the last group.

The replication was expected to answer to the probability that color-blind subjects and expressly deuteranopic subjects do not actually perceive the light directed toward the background of the eye. This replication could, at the same time, be taken as a sort of cross-validation of the question to what extent could the critical class of color-blind subjects be validly discriminated from the rest of the subjects by means of the observed reactions in the light test.

The results of the replication are summarized in Table 3. The reader is asked not to mix the quantitative indication of color weakness with the classification of color blindness. As might be evident from the foregoing discussion of the reliability problem, the conventional subtypes of anomalous trichromatism cannot be predicted on the basis of the "sum score" indicated in the fourth column. Actually the subjects included in the first two groups are, according to Ishihara's conventional classification, deuteranomalous trichromats or deuteranopic dichromats. Because the differentiation between protan and deutan types is actually based on only four charts with stimulus number (plus a couple of charts asking the subject to trace a line) the whole determination of dichromacy or strong anomaly is probably not very reliable. But under these conditions cases 1, 5, 7, 9, 12, and 14 are to be considered as the most distinct deuteranopics. If we take into account the number of normal responses, cases 1, 5, 9, 14, and 17 are the purest deuteranopic dichromats, while the rest are to be considered deuteranomalous trichromats of various degrees of severity. Special attention is paid later on to "unilateral" case, No. 16, and to the rest of the middle group.

Again rather a considerable proportion of color-blind subjects failed totally (or almost totally) to perceive any change or any light whatsoever directed through the background of the eye. The listed results converge with the prior results, including the annoying exception of a deutan subject who actually was able to perceive the light. In spite of this exception, the difference is without doubt significant between the means of the first group and two last groups combined, or between the first or the first two and the last alone. The average number of correct reactions also increases systematically from first group to last. If a minimal number of correct reactions (0 or 1) had been used as a cut-off score we would have been in error if this test had really been used as a criterion of this type of color-blindness. But the question of the validity of this procedure cannot be and was not intended to be seriously treated here. Instead we may attribute decisive significance to the conceptual side of the finding. This is, in our opinion, concealed in the possibility of interpreting the *lack of perception as depending on insensibility to light* and *not merely to color.* We may then speak of light blindness in the same sense as we did in

TABLE 3

Original and Combined Scores in Ishihara Test, Index Showing Lateral Asymmetry Between the Eyes and Recordings of Reports When Light Was Directed Toward the Fundus Oculi

Subject	Ishihara Response: Normal	Color-Blind	Sum Score	Lateral Asymmetry Index	Light Test Reactions	Verbal Report
Group I Color-blind						
1	2	25	-23	2	12	Light from below, darker and brighter.
2	7	17	-10	5	0	No changes; claimed afterwards that he saw small dots all the time.
5	1	23	-22	6	1	Once, very faint light.
6	5	17	-12	5	0	No changes, nothing.
7	6	20	-14	3	0	No changes, nothing.
9	0	25	-25	1	0	No changes, nothing.
12	6	21	-15	6	0	No changes, nothing.
14	2	27	-25	3	0	No changes, nothing.
17	1	30	-29	3	1	Short flash on right side.
Group II Color-weak						
4	16	10	+ 6	7	3	Once, light from below.
13	16	11	+ 5	5	3	Vertigo, flash of light.
16	20	14	+ 6	11	7	Blots of yellowish light on left side.
18	13	10	+ 3	14	11	Dots of white light, no direction reported.
Group III Color-normal						
3	48	0	+48	0	11	White light from above.
8	48	0	+48	0	10	White light in the eyes and outside.
10	32	6	+26	4	11	Flashes of white light from below.
11	45	0	+45	3	12	Red flashes of light, direction indefinite.
19	41	0	+41	2	12	Red flashes of light in front.

connection with, for example, the retinopathies in the first trial. This insensitivity may be transient and it may depend on some external factor or other, but insofar as we may accept the existence of the insensibility as such, it is a point of view from which a *color-blind subject can actually be considered to be light-blind*, not color-blind. The external factor may be an acceleration or inhibition of the development of some "opsin," or specific non-transparency or even color of the background or other intervening tissue. However, important in our opinion is that insensible subjects do not see shades of white or gray in the presence of most probably red stimulus, but see nothing. (The postulation that color-blind subjects generally see shades of gray where color-normals see some color may be erroneous altogether, but this is immaterial for the present argument (Weckroth, 1969, p. 182).

The approach is, of course, open to criticism. Direction of light, size and location of the patch on the retina, time and quality of adaptation, and duration of stimulus are some of the most relevant characteristics which determine actual perception under normal conditions. Some of them, or those expressly listed, may be even more central when light is directed on the retina from an entirely reversed direction. It had thus to be admitted that in addition to the loose frame of response, lacking an exact determination of the shape, brightness, hue and direction of light eventually perceived, there was a group of factors possibly affecting the outcome of the phenomenon which were weakly controlled. Thus an incidental factor could account for the main outcome itself and for the exceptional presence of the series of correct reactions in particular.

Lack of fixation, for example, could easily be referred to as a source of error. Without rigid fixation there is no control of the direction in which, or area where, the light falls on the retina. Moreover, even the closing of eyes and mouth were not very rigidly controlled nor the position or movement of the test tube. On the other hand, more systematic inquiry into the verbal reports might have revealed, for example, that the exceptional case projected the image of light downwards, because he did not perceive the light until it reached the opposite side of the eyeball after having ineffectually penetrated the retina. By listing such underlying factors we can hope that the continuation of the study will be able to solve them or take them into account. Among the sources of error there is one which might already be treated a step further and that is the adaptation problem. From the point of view of the theoretical argumentation applied here the adaptation problem is essential. It may focus our attention because it may expose the possible methodological power the unilateral cases might have in this connection (and not only with respect to the adaptation limit).

The question is whether insensibility to light directed through the background of the eye is of a transient nature or not. The attainment of the theoretical goal depends upon whether the lack of perception of light is due to a specific duration of adaptation or not. From this point of view the unilateral cases are in a key position methodologically because they can be considered as being their own control. In the second sample there is one even clearer unilateral case (Graham & Hsia, 1954; Graham & Hsia, 1953, pp. 281-95). In this case the eyes diverge from the theoretical average value almost equally as much, but in opposite directions. The subject has an almost equally large "normal" score on the left side as he has "color-blind" on the right side. In the light test he spontaneously reported sensing the light expressly and only on the left eye's side. The categorial tendency to "see or not to see" seems thus to be accentuated within one and the same individual, provided that the difference is great enough between the eyes. Therefore, the question arises, if the time in the dark has been enough for one eye, then why not for the other? The possibility that the response is absent on the right side because adaptation proceeds more slowly in a color-blind eye does not as a matter of fact seem very probable. So much the less since we learn from Saugstadt (1959) quoting Uthoff and Hecht, et al., that adaptation to the dark of color-blind subjects is *faster* than the adaptation of color-normal subjects. The possibility

that the color-blind eye has a prolonged adaptation due precisely to the unilaterality itself does not seem very plausible either. If it is actually true, we are faced with an even more difficult question as to the nature of such double adaptation. Worthy of consideration is the evidence presented by Rushton, showing[10] that the permeability of the retina, in terms of absorption, varies as a function of the level of adaptation. So, with respect to where the response originates, the adaptation phenomenon might be decisive. Inasmuch as we may assume that the observed effect is restricted and based on the immediate influence the light has on the back of the retina, the problem may be left undecided. Under these conditions it seems probable that the insensibility is not, at least in the bilateral cases, due to a prolonged adaptation connected with the color-blindness. It might be due to the possibility that the adaptation proceeds faster, but also in that case we may conclude that the insensibility (i.e. the basis of the absence of reactions) is not a transient but a permanent characteristic reflecting an insufficiency, malformation, or overdevelopment of some fundamental component.

The unilaterally positive finding also throws light upon directional and areal factors as sources of error. Accordingly, it seems rather unlikely that the existence or absence of positive reactions is essentially dependent on these dimensions either. When a unilateral case reacts with one eye as color-normal peers do, and reacts with the other eye as the majority of color-blind peers do, it seems unreasonable to assume that the color-blind peers happened not to see the light because they had their eyes in a different posture than the rest of the group. So all in all the unilateral case strengthens the early impression we had about the "all or none" regularity the phenomenon seems to obey.

The impression was confirmed, of course, by the conception of the categorial nature of color blindness and by the possibility, a priori, of referring to certain permanent structural factors which might explain the absence of sensitivity to light. A probable explanation is the complete absence of pigment, as evidenced in the studies of Rushton (1958), Wald (1960), and Weale (1966). The results obtained are not quite uniform and the loss-theory has also been criticized (Gregory, 1966, pp. 126-29). It is assumed that one factor determining color weakness is the lack of pigment in both deuteranopics and protanopics--at least in the latter, and Wald claims its absence in the former as well. A variation of this view is that some pathological location of the pigment might explain blindness to both color and light (Dartnall, 1960, p. 160). A further possible explanation is associated with observations of an especially general fall in sensitivity in color-blind subjects (Hecht & Hsia, 1947; Wald, 1966, p. 1358). It would, of course, be simplest to explain that blindness to light is a consequence of higher (than normal) absolute threshold values. Wald to some extent doubts any general rise in threshold values, but arrives at results similarly indicating the sensibility of deuteranopics as weaker, though the difference is not significant. The fall in sensibility is observed precisely in connection with dark adaptation. A third possibly relevant structural factor here is the Stiles-Craford effect, the dependence of light effectivity upon angle of incidence on the retina (Pirenne, 1967, pp. 47-51). The same light is thus weaker in its effect upon the same retina, the further its angle of incidence diverges from the optic axis. It is symptomatic that the angle gradient here is selective in respect to color, and that the loss of effectivity is greatest with red, diminishing gradually toward shorter wavelengths. If the Stiles-Craford effect can be imagined to extend to the other side of the retina it might be thought to narrow (in the manner of a raised threshold) the conditions under which light reaches the receptors and is sensed. The angle gradient might thus constitute a significant additional factor which, in combination with the above, would bring about an absence of reaction. Its effect would not, on the other hand, emerge in the normal eye possessed of both pigments or normal threshold. An orientating approach is of course insufficient for a more precise definition of the channels of influence. The theoretical significance

particularly of the latter factor could be noted in regard to future research. It is associated with the fact that what is involved is a gradient of *angle*, which in addition may be critical, especially with regard to reflected light. It should be noted also that it is a question of gradient of an angle which is distinctively different in connection with different colors or anatomically different receptors (rods and cones, Pirenne, 1967, p. 49).

The Ishihara test is not normally carried out for each eye separately. In this connection we feel a number of comments are necessary. The critical unilateral case--or rather the concept of unilaterality--is critical for the criterion. What is the message of unilaterality, how contingent is such a case, and how reliable are any conclusions drawn on its basis? The center of emphasis is the middle group, in the following analysis.

Sub-series may be distinguished among the Ishihara tables according to whether the item provokes only color-normal, only color-blind, or both, to perceive the intended figure (Ishihara, 1960). Predictability (from eye to eye or from item to item) may be scrutinized starting from the last mentioned series, which due to its discriminative capacity has been used as a screening set (Wald, 1966, p. 1349). On this basis the four cases in the middle group (Table 3) would be diagnosed completely differently. Case 4 would be diagnosed as completely normal; Case 13 as totally deuteranopic; Case 16 left eye normal, right eye deuteranopic; and Case 18 as mixed (perhaps tritanopic). So, it is observed that the members of this (statistically very small) group in fact differ strikingly from one another but represent fairly pure subgroups. On the basis of these differences it cannot be predicted that the members of the group respond in completely identical manner to the following series, which as a rule provokes only the color-blind to perceive a figure. They all prove normal. In the next series, again, all of them show occasional unipolar normal responses, usually two and, notably, irregularly on one side or the other except Case 16 who is most markedly unilateral. In the remaining series of items, all belong to a minority again in showing occasionally normal responses.

Thus the middle group in Table 3 formed on the ground of dominantly normal response sum in the Ishihara, is not intermediary in its color blindness in the unidimensional quantitative sense. Rather the group would be located at the apex of a triangle having as its base angles color-normal and color-blind, respectively. In actual fact, the middle group forms a miniature triangle itself, with the clearcut unilateral case as its apex. In the psychometric view it could be said that in place of internal consistency there is internal conflict. The reliability problem proves exceptional in the middle group as well. The limited size of the trial for any actual statistical conclusions must of course be borne in mind, but its organization suggests that the color blindness classified here is as a syndrome at least two-dimensional, and that the poor predictability is consistent. In other words, what prevails between the eyes correlates with what prevails within them. Be it noted that the conclusions concern the main group of deutan-type of color blindness.

On this basis it may be envisaged that there may also be, as Willmer has proposed (Wald, 1966, p. 1349) two types of deutanopia. It is also justified to accept the comment of Ripps and Weale that the loss system is probably insufficient in itself as an explanation of color blindness (Ripps & Weale, 1969; Gregory, 1966, p. 129), and the observation of the difficulties "that arise for genetics when color anomalies are treated as states intermediate between normality and dichromacies (Ripps & Weale, 1969, p. 210)." The most significant interpretation from the theoretical point of view is associated precisely with the poor predictability of responses; the difficulty of predicting answers from one eye to the other and from one series to the next. The group showing discrepancies between the eyes also proved to be the extreme group in "internal discrepancies" within the eyes, because unipolar plus and minus answers are extremely rare in both the color-blind group proper

and in the normal group. One has the impression that at this level color blindness is expressly an interaction problem. The modal is seeking a state of peaceful coexistence between the eyes. The purest unilateral case seems to have achieved the optimal situation, but here too not completely, as corresponding cases have previously shown (Graham & Hsia, 1953, 1954). From this standpoint one might claim that discrepancy between the eyes in fact reflects an internal interaction problem of the eyes (perhaps specifically of one eye). In other words the discrepancy between the eyes emerges, because color blindness is (at least in respect of its component factors) an interaction problem of fields or channels.

There is normally interaction between the eyes. It is observed, for example, in the shades of "parasite colors" or color aftereffects produced by achromatic stimuli. The shades can be changed by changing the "inter-eye light intensity."[11] It may be assumed that the development of a unilateral syndrome is based essentially upon the same interaction mechanism as instantaneous interaction. On this basis poor internal predictability would be easy to explain by reference to deficient or inflexible interaction between receptors and fundus, and between eyes. The closing of the other eye, it may be assumed, fixates a certain balance level on which the patches of the pseudochromatic charts are distinguished or not, particularly as to brightness and not only to hue.

If the variegated intermediary cases may be regarded as correlates of certain phylogenetic phases of development, sequel studies must pay particular attention to this area. For the moment it must suffice to note that the number of intermediary reactions in the light test seem to be associated with poor inter- or intra-eye predictability, but also that the accumulation might be a coincidence. It might also be due to a characterological factor connected with the uncertainty of the observation. All in all, however, the criterion characteristic has proved to be an unexpectedly complicated matter.

Normal Subjects

There is no need for a table listing the observations of "normal" subjects. All of them reacted correctly after each stimulus flash, as did the control cases in Table 3. We conclude this report of an apparently unknown phenomenon by a description of what was seen by our normal subjects.

Actually, half the cases claimed the light to be reddish or pale whereas the other half saw it as more or less white. The shape seen resembled the form of a northern lights and shadows, and may be due to the curved bone below the eyes and the possible fact that the light spread otherwise freely on the retina. The image is usually projected upward in front of the eyes. The hue or brightness seems not to alter due to the length of exposure or dark-adaptation; nor does the flash seem to have substantial contractive effect on the pupil. In the training period, some subjects revealed that some stimuli can be missed in the beginning due to the difficulty of distinguishing the actual stimulus from different possible aftereffects. Since the correct stimulus was detected the subject was able to react correctly each time. The same categorical trend was also observed in connection with blind and color-blind subjects.

The difference in hue of the flash could be attributed to the position of the eye (refer to the Stiles-Craford effect). It could be mentioned, however, more curiously, a phosphene caused by an electrical current has been identified in two distinct hues, either yellow-red or blue-white depending on whether the current passes outward or inward through the retina (Duke-Elder, 1968, p. 466).

CONCLUSION

An attempt was made to show that man normally sees light directed through the fundus of the eye. At the same time, some conditions have been brought out in which this light perception is obstructed. Accordingly, one contributory factor in

blindness may be an obstacle or an opaque medium blocking the light, even in cases where it is behind the retina. In examinations of color-blind subjects it was observed that a certain type of deuteranopic dichromasia might be a result of the insensibility of one receptor type, which could be called light-blindness. It was not determined whether or not the dysfunction was caused by the light coming from behind. The normal individual perceives light introduced from behind either without or after a very short period of adaptation. The perception is based on irritation of the back of the retina, but might possibly be due to light scattered throughout the eye.

At the same time, and independently, a device was developed, mainly through experiments with cats, which made it possible to project light directly to the back of the retina (del Campo, 1971). The idea was to evolve a technique to assist a certain group of blind subjects in whom the macula lutea was intact in spite of pathological developments in the preretinal regions. The principle of direction was the same, but required surgery. Nor can it be claimed that the capacity of the retina can be preserved for long if it is directly affected by light. It is evident that the light tube herein described could be developed into an inexpensive appliance which a subject preretinally blind but retaining the sight capacity of the retina, might use to facilitate limited vision.

The fact that man is capable of perceiving light directed through the back of the eye does not of course justify the conclusion that light coming from such a direction is of functional significance in normal vision. If it is involved it must be noted that the light is by nature reflective. In principle the receptive qualities of the eye may be different from what we know. Any conclusion as to the significance and effective mechanism of light reflected from behind the eye must be drawn with caution. However, one is forced to take some sort of stand by the fact that the phenomenon emerged on the basis of theoretical reasoning. It seemed that a number of light-perception and visual phenomena might be more simply explained if we assumed that in part of our perception the outcome is determined by a combination of light itself and its reflection from the fundus.

In the introduction the bipolarity of certain sub-functions was referred to as a general principle. The eye seems to deal with light energy as the hand deals with an object by thumb and other fingers operating in opposite directions. Perception takes place as a result of a clearly bipolar effect in which the apparently centrally determined efferent control plays an essential part. Additional external symptoms of the double strata of the structures include, above all, the leap observed in connection with the Purkinje phenomenon, the obviously dual dark-adaptation curve.

The *activity or dominance of the strata is clearly a correlate of the amount of light.* Although the retina here is assumed to be, for the most part, permeable, the receptor and pigment layers form a natural limit, which normally are located so that perception is based mainly on light coming from the front and partially on light coming from both front and back. A further correlate of the amount of light is the double structure of the main classes of receptors, rods and cones. For example, change in permeability as a function of dark-adaptation, the distinctively different processes of the opsins as well as the distinctive location of the Stiles-Craford effect might be regarded as factors promoting exhaustive treatment of light energy on the basis of this kind of balance structure; the last-mentioned especially in connection with reflected light.

As internal factors supporting the assumption of the central significance of reflected light or possibly connected with it, mention might be made first on the angle-gradient of the receptors. One argument here would be that the angle-gradient seems to be associated explicitly with the function of the receptor type (red), and which may be assumed to participate more actively in perception of light energy coming from two directions and hence be relatively greater. Furthermore, inasfar as we may assume the angle-gradient of the receptors to function in the manner of a polarized filter, it would function precisely as in the case of reflected light. This would

change it into a real direction-gradient. True, it must be noted that the restriction of the Stiles-Craford effect to the cones has been observed only in the case of light coming from the normal direction. The comment of Pirenne that the effect of the rods depends upon light-adaptation may be of significance in this context (Pirenne, 1967, p. 49). A further internal structural argument would be the evidence that the role of the fundus oculi is essential in light scattered in the eye (Vos, 1963). In connection with the observation once reported by Dartnell that the opal media gather reflected light, the light reflected by the fundus might also perform a special informative function, because light is collected and is perhaps also directed selectively as a function of wavelength (Dartnall, 1960, pp. 156-58).

The above connection of the angle-gradient with the rods independent of the level of adaptation and to the cones dependent on it, may be precisely an indication of the distinctive significance of reflectance with regard to the amount of light. Let us suppose that effectivity changes, in the case of the cones, as a function of direction more markedly because the perception was essentially affected by light reflected from the background. From this point of view it may be extremely relevant that the effectivity of red falls most sharply as obliqueness increases. A number of other phenomena could be listed which place red in a special position, phenomena which for their part verify the role of the fundus, bearing in mind that the fundus is homogeneously red. Such indicators include the adaptation curve, perimetric color fields, the sensitivity curve of protanopics, the early learning of red and so on. In outward physical reality, one might note that red is perceived at both ends of the spectrum, to say nothing of the biological significance of this color.

Central to the theoretical argument adopted here is the consideration of the eye as a differentiated subsystem of the brain. The chief question in instantaneous perception is how the eye can distinguish and recognize colors when the neural process is demonstrably capable of registering only variations in quantitative frequency and amplitude. The essential question from the viewpoint of the evolution of the servosystem is how the subsystem could have evolved from a more simple monogenetic state characterized by one receptor (divided in gaussian fashion as to its sensitivity). It is sought here to see the combined influence of the permeability of the retina and the reflectance of the fundus as factors forming a basis for both the development of the servomechanism and the balance of the bipolar components.

As part of the servosystem the theoretical "primary receptor" must be assumed to possess a certain universality. In cooperation with the brain it must be a kind of Turing universal machine capable of solving all problems of reaction to environment arising and embracing all the variations subsisting in the later differentiated developments of it. The demonstrated power of the eye to receive light authentically from the fundus, in our opinion allows the possibility of seeing in a simpler fashion than hitherto, what is universal in the receptor. The task of the optic receptor is of course to observe the environment. Its turning may be understood simply as an early variation on this theme. Universal in the operation of the receptors is interaction. In turning to its background the receptor is realizing its earliest mode. This turning may be seen to form the basis for the tendency to interaction generally characterizing the receptor function and manifested between the fields of the retina, the types of receptor and, on the macroscale, also between the eyes. In the treatment of information, the turning is, in principle, the hinge which opens the development toward a "comparative" resonant "perception" in addition to the rigid "detection-type" perception. Reversal away from the source of light is only ostensibly detrimental. It evidently forms a sufficient but also necessary condition for resonant perception of a higher level than rigid instinctual perception. It is, as an outcome of intentional activity, in principle analogous to the "creative perception" with which the bat and the dolphin sense the minutest differences in energy in their

environment by producing sounds themselves which are then received as echoes.

In his treatment of the kybernetic aspects of perception Klix has recently stressed the central importance of apprehension of "proportion" and *mittelwertbildung*. In this context he notes how inadequate the mere "measurement" of the amount of radiational energy of an object would be (Klix, 1971, p. 243). In concordance it might be claimed that the change (or loss) involved in the "reversal" of the receptors, is concentrated specifically upon this very possibility of measuring the amount of energy or differences in it as such. At the same time it has of course meant that the value of formal stimuli (form) has in a sense given place to that of relative stimuli (hue). On top of this one finds oneself apparently obliged to accept such inaccuracies as the Mach bands and the apparent colors of achromatic stimuli. These are, however, phenomena brought out mainly in extremely precise laboratory conditions. Some of these symptoms may indeed derive from the fact that the fundus is in reality multistratified because of the pigments and thus endowed with a more complex functional role (Pirenne, 1967, p. 181). The ultimate underlying aspect in all of this is the absorption--reflection ratio of the original fundus, the constant quality which in a long process of genetic selection has been able to split the (double-peaked) receptor distribution.

This imagined evolution is clearly in keeping with the known spectral sensitivity distribution of the receptors. If, in addition, we take into account the red emission spectrum of the fundus, the phylogenetic (or ontogenetic) coding of color could scarcely derive from factors of any simpler structure. Let us suppose that one of the receptor units--including the pigment--could receive light from either direction. It could then distinguish and identify light of the same color as the fundus solely on the basis of intensity because the loss of energy in feedback of the same color would be minimal--red. The maximal loss, again, would be with the complement of red--green. This would follow the pattern of balance proposed by Gothlin, and for red-green that of Hering as an explanation of the Bezold-Brucke phenomenon with respect to its yellow component. Characteristic of the split in spectral sensitivity, distribution would be a balance between the amount of light meeting the receptor from either direction. Thus, hue would also be dependent upon the intensity of light. It may be supposed that from the brightest point of light energy onwards, an ever greater proportion of the reaction of the eye would constitute protective functions. Actually, it is evident that the protective and orientative response of the eye to amount of light could not subsist without some basic level--the fundus--with which the varying amount of light is comparable. It is undetermined how far the photochemical process of a given pigment is essentially regulative with respect to reflecting light.

A structural detail of significance from the achromatic standpoint, in principle involved in the split of spectral sensitivity distribution, comprises the horizontal neural connections. These of course maintain contact between the different groups of receptors. It is quite clear that their basic functions are of a kind which depend upon interaction. There is as yet no general agreement as to how they participate in various spheres of activity. It has been suggested, for example, that the regulation of average perception, explicitly in connection with achromatic stimuli, is based upon the function of the horizontal cells (Klix, 1971, p. 242). It has also been proposed that antagonistic part processes in the receptive fields might be manifested at various levels of transversal contact (Glezer, 1971, p. 43). The essential point, however, is that the interaction required by the subareas can, in general, only take place against some background. The horizontal neural connections, which possibly represent an evolutionary counterpart to the background of the eye, and actually in respect to their location do constitute a structural counterpart on the other side of the retina, are also a functional counterpart of the fundus. In this envisaged development, then, the status of the fundus is paradoxical. It affords the only condition of function for the cooperation of the receptors,

differentiated because of it. The duality of the horizontal neural contacts may thus be considered a kind of redundancy which, for its part, indicates the significance of the connection. With reference to the analysis by Glezer (1971, p. 41), it should be emphasized here that co-operation is likewise not envisaged as based on scattered light, although this may be taken into account as one possibility.

In an assessment of the so-called degeneration or disintegration methods Dekking once remarked, "even if it does not give you a clear insight into the structure you are studying, at least it gives you a clear insight into the deficiencies of your theory." The comment seems appropriate to our concluding discussion of an open question associated with the validity of the evidence of color-blind subjects. On the basis of perception of light coming from behind we feel it should be possible to create a coherent picture of the modal development of vision and the present situation such as would agree with the known neurophysiological facts. In developing the picture, stress has been laid especially on the position and location of the elements as of prime significance in interaction. It is claimed that the universality of the centrally regulated peripheral elements lies also in their positioning with regard to each other. But to what extent is it adequate to regard the absence of reaction to light in deuteranopics as an indication of the development imagined, especially since the subgroup, which in actual fact lacked the reaction, was contrary to expectations?

The subgroups of color blindness are clearly mutually divergent as to their symptoms. Its favor as a verification of theories derives precisely from this. In theory it has been justified to expect light reaction to be absent in color-blind subjects in general. Certain differences were to be expected in this area, for example, because the permeability of the retina is found to vary as a function of the effect of light (Rushton, 1952, p. 47). In undertaking the experiment we were aware of the ambivalence. It was not certain whether the absence of reaction was due to the fact that the light came from behind or the fact that it was red. In the case of deuteranopics the problem of sequel studies is also a dual one. The reaction may be lacking because the light is not distinguished from the base light experienced by the closed eye, or because the light does not penetrate or affect the pigment of a certain receptor unit. From the fact that the visibility curve of deutan subjects is characteristically higher than that of protan subjects, it might be assumed that returning light exerts an inhibiting effect on the reaction of the receptors. It is also known that the spectrum of a protanopic is contracted at the long wave end. Here one could use the term light-blindness in the sense intended in this report. Let us suppose that the deutan receptors proved contracted in the same way but with respect to returning light. The method applied here does not allow of any conclusion as to the precise role of red in the absence of reaction. We may thus assume that the blindness would concern at least the complement colors of the deutan receptor. On this basis it would be more natural to expect lack of light-reaction on account of the failure of returning light to penetrate or stimulate the deutan receptors. (There is scarcely more than a theoretical possibility that the blockage of reaction would derive from differences in the pigment of the skin of the fundus.) A concrete idea of how black red can be may be gained by examining a red surface through a narrow band green (or blue) filter.

NOTES

1. There is a marked "jump" in adaptation curves, Purkinje "shift," "neutral points" accentuated in Bezold-Brucke phenomenon, all indicating shifts of the reaction from one substructure to the other, or loss of the other, or that both are responsible for that reaction.

2. Monogenetic is the simplest form of theoretical assumption concerning the start and development of the retinal receptor units from one single type of unit (receptor + pigment + electrochemical properties + neural connections) having originally a certain sensitivity distribution. The other possibility is naturally the polygenetic assumption, postulating that from the beginning there have been two or more different receptor units or mechanisms.

3. Polyak (1941) counts cornea and retina as the transparent media of the eye, stating that the first is entirely, the latter, in greater part of its thickness, transparent. But this statement is found in the introductory general outline of *The Retina* and the property is not treated in the proper context. Nor is the transparency or permeability of the retina or the reflectance characteristics of the background of the eye (Duke-Elder, 1968). Rushton and Weale (Duke-Elder, 1968, Vol. IV, p. 477) form an exception in this connection. The method concerned is essentially based on transmission and absorption properties of the retina, and will, therefore, be treated later.

4. It can be mentioned in this connection that the third author who served as a first subject (outside the carrier of this peculiar idea) was very soon able to perceive the light flash even in normal daylight illumination.

5. The duration of the stimulus flash was not controlled nor was the reaction time which was accepted as a "prompt answer." The experimenter was asked to push the switch equally long and it was found that subject's reaction came in one or two seconds or not at all. In this type of proof, more accurate control of the input and output were not considered necessary, but it is realized that the duration of stimulus might be an essential criterion if the number of receptor types responsible for the reaction is more than one. In continuation of the study these questions will be treated further.

6. The majority of the blind subjects were tested at the Tyyskyla Rehabilitation Center for the Blind during their participation in a rehabilitation program. The rest of the subjects were tested at The Eye Clinic, University of Tampere, as a part of a diagnostic work.

7. This trend, if real, could naturally be utilized as a differential diagnostic tool, together with the self-evident find that if the eye does not see light from either of the directions, the defect is most probably neural, that is, a defect caused by atrophy or surgical ablation. These possibilities will be treated in another paper.

8. The test for color-blindness (Ishihara, 1960) is given in Finland in some elementary schools for vocational guidance purposes.

9. Over one hundred subjects were later gathered for a replication of the results. Both eyes were tested separately. The color-normal subjects formed the control group.

10. According to Rushton and Weale (1968) a considerable amount of light coming through the lens passes the retina twice, the amount being naturally dependent on the composition of the light, but also on the level of adaptation. See Note 3. The method is described in principle by Rushton (1958, p. 73).

11. We wish to replace the term subjective color with the term *parasite color* to pertain to the experience of colors in connection with achromatic figures and backgrounds. An example of such a color in connection with stationary figure-background conditions is given by Weckroth (1969, p. 182). An example of the alteration of the hue of an afterimage as a function of light intensity see Weckroth (1964, pp. 67-74). The interaction between the eyes has been overlooked as a possible general source of error in experiments where one eye is used as a control of the other.

REFERENCES

Beetham, W. P. Visual prognosis of proliferating diabetic retinopathy. *British Journal of Ophthalmology*, 1963, 17, 611-14.

Caird, F. I., & Garrett, C. J. Prognosis for vision in diabetic retinopathy. *Diabetes*, 1963, 12, 389.

del Campo, A. Iconophoresis: A new technique for obtaining macular vision in some types of blindness. In T. D. Sterling, E. A. Bering, Jr., S. V. Pollack, & H. G. Vaughan, Jr. (Eds.), *Visual prosthesis: The interdisciplinary dialogue.* New York, London: Academic Press, 1971, pp. 129-133.

Dartnall, H. J. A. Visual pigments of colour vision. In Y. Galifret (Ed.), *Mechanisms of colour discrimination.* London: Pergamon Press, 1960, pp. 147-61.

Duke-Elder, S. *Systems of ophthalmology.* London: Kimpton, 1968.

Glezer, V. D., Bertulis, A. V., Ivanov, V. A., Kostelyanets, N. B., & Bodvigin, N. F. Functional organization of the receptive fields of the retina. In G. V. Gersuni (Ed.), *Sensory processes at the neuronal and behavioral levels.* New York, London: Academic Press, 1971, pp. 19-46.

Graham, C. H., & Hsia, Y. Luminosity curves for normal and dichromatic subjects including a case of unilateral color blindness. *Science*, 1954, 120, 780.

Graham, C. H., & Hsia, Y. Some visual functions of a unilaterally dichromatic subject. In National Phys. Lab. (Ed.), *Visual problems of colour.* London: National Phys. Lab., 1953, pp. 281-95.

Gregory, R. L. *Öga och hjärna.* Stockholm: Aldusuniversitetet, 1966.

Hartline, H. K. The receptive fields of optic nerve fibers. *American Journal of Physiology*, 1940, 130, 690-99.

Hecht, S., & Hsia, Y. Colorblind vision. I. Luminosity losses in the spectrum for dichromats. *Journal of General Physiology*, 1947, 31, 141-52.

Hubel, D. H., & Wiesel, T. N. Receptive fields, binocular interaction and functional architecture in the cat's visual cortex. *Journal of Physiology*, 1962, 160, 106-54.

Ishihara, S. *Test for colour-blindness.* Japan: Kanehara Shuppan Co., 1960.

Klix, Fr. *Information und Verhalten.* Berlin: VEB Deutscher Verlag der Wissenschaften, 1971.

Kuffler, S. W. Discharge patterns and functional organization of mammalian retina. *Journal of Neurophysiology*, 1953, 16, 37-68.

Miettinen, P., & Weckroth, J. *Early detection and measurement of retinopathic changes in connection with diabetes mellitus.* (in preparation.)

Pirenne, M. H. *Vision and the eye.* London: Chapman and Hall, 1967.

Polyak, S. *The retina.* Chicago, Ill.: The University of Chicago Press, 1941.

Pribram, K. *Languages of the brain.* Englewood Cliffs, N.J.: Prentice-Hall, 1971.

Ratliff, F. *Mach bands, quantitative studies on neural network in the retina.* San Francisco, Calif.: Holden-Day, Inc., 1965.

Ripps, H., & Weale, R. A. Color vision. In P. H. Mussen, & M. R. Rosenzweig (Eds.), *Annual Review of Psychology*. Palo Alto, Calif.: *Annual Reviews*, 1969, 20, 193-216.

Rushton, W. A. H. The cone pigment of the human fovea in colour blind and normal. National Phys. Lab. (Ed.) *Visual problems of colour.* London: National Phys. Lab., 1958, pp. 73-105.

Rushton, W. A. H. Electric records from the vertebrate optic nerve. *Journal of Physiology*, 1952, 117, 47. *(Brit. Med. Bull.*, 1953, 9, 68-74.)

Safir, A., & Rogers, S. H. The relationship between duration of diabetes and presense of retinopathy. *American Journal of Ophthalmology*, 1970, 69, 387-92.

Saugstad, P. A. The duplicity theory. *Advances in Ophthalmology*, 1959, 9, 1-51.

Vos, J. J. Contribution of the fundus oculi to entoptic scatter. *Journal of Opt. Soc. Am.*, 1963, 53, 1449.

Wald, G. Defective color vision and its inheritance. *Proceedings of the National Academy of Science*, 1966, 55, 1347-63.

Wasserman, G. Invertebrate color vision and the tuned-receptor paradigm. *Science*, 1973, 180(4083), 268-75.

Weale, R. A. The perception of colour. *Discovery Journal of Science*, 1966, 27, 31.

Weckroth, J. Black and white colors. In J. Jarvinen (Ed.), *Contemporary research in psychology of perception.* Porvoo: W.S.O.Y., 1969, 175-82.

Weckroth, J. *Studies in colour after-images.* Helsinki: Suom. Tiedeakat, 1964.

BLIND MOBILITY CURRENT RESEARCH PROGRAM

John Armstrong*

The research program is a wide-ranging investigation into the problems experienced by blind people during independent mobility.

Each project within the main program is aimed at gathering basic information about the nature of specific mobility problems and seeking practical solutions to those problems. In some cases, the results of research have already been communicated to mobility specialists and welfare workers so that changes in the provisions of mobility services throughout the country have already started to take place.

Parallel with these practical developments, the research group continues to pursue more basic lines of investigation which are intended to form the foundations for future development.

THE OBJECTIVE EVALUATION OF MOBILITY PERFORMANCE

The central problem in assessing the efficacy of mobility aids or mobility training programs has been the lack of objective measures of mobility performance. An objective procedure, which assesses mobility performance in terms of safety, efficiency and level of psychological stress, has been worked out.

A number of new mobility aids, including the Binaural Sensory Aid, the Sonar Cane, and the Swedish Laser Cane have already been evaluated using the assessment procedure. The relative merits of the individual aids, with respect to safety, efficiency, and reduction of psychological stress have now been catalogued but none of them so far evaluated show an overall superiority on all of the performance measures.

The research group contributes to a sub-committee of the National Academy of Sciences and much of the assessment procedure used here is shared by various research groups in the United States.

LONG-TERM EVALUATION OF MOBILITY AIDS

The improvement in mobility performance which follows training in the use of a particular mobility aid may be transitory and some of the problems resulting from the use of that aid might not emerge until after long periods of continuous use. At the same time, mobility performance with certain aids might well improve as more experience with the device in question is gained.

Although the evaluation procedure provides information on improvement in performance at the time of training, it does not predict the effects of periods of free use with the aid. It is accepted that the advantages of a particular device to its user might not necessarily be in terms of mobility improvement but could be reflected as a beneficial

*Director, Blind Mobility Research Unit, University of Nottingham, England.

change in life style. Accordingly, measures of blind individuals' self-esteem (see "Measurement of Adjustment to Blindness") have been made prior to training with mobility aids and taken again at intervals during a three year period.

HEART RATE AS A MEASURE OF PSYCHOLOGICAL STRESS

A series of experiments has been carried out to examine a possible relationship between instantaneous heart rate and specific environmental events. It was hoped that, if such a relationship could be established, instantaneous heart rate might be used as an objective measure of the effectiveness of individual aids in providing appropriate information about complex and stressful mobility situations. However, it has been found that it would be exceptionally difficult to control for work output over very short periods of time, therefore it is concluded that instantaneous heart rate is not a practically useful measure of psychological stress in mobility situations.

THE MOBILITY OF THE DEAF/BLIND

Because of their inability to make effective use of sound sources for orientation purposes, the deaf/blind cannot normally be given advanced mobility training. A survey has been carried out among mobility specialists and many of the problems encountered in attempting mobility instruction for the deaf/blind have been isolated.

A series of experiments have been carried out to establish the accuracy of sound localization that different hearing aid systems would allow. The localization ability of normal hearing subjects was measured under both monaural and binaural conditions to provide a baseline against which performance with different hearing aid configurations might be compared. The effect of head movement on accuracy of localization was also examined.

It is concluded that the use of two chest-mounted aids leads to an overall raising of mobility performance and a particular improvement in the objective measures related to orientation. No comparable data is yet available for post-aural aids or for deaf/blind subjects.

MOBILITY MAPS

In addition to the detailed information about the immediate environment provided by conventional mobility aids, the blind person also needs to know about the organization of a large segment of his surrounding environment so that appropriate progress towards required destinations can be maintained.

Nearly 500 copies of our publication which outlines work on the standardization of maps done here have been distributed to mobility officers, teachers, and social workers and a follow-up study involving ten mobility officers is being carried out in order to evaluate its success in providing the necessary information to enable complete amateurs to make mobility maps.

As a further step towards standardization, we will soon be marketing a kit of point and line symbols which will enable unskilled map makers to construct high quality master maps from which thermoplastic copies can be taken.

Experimental maps of a large shopping complex and a complicated pedestrian subway system have been produced and evaluated. Results show that the maps, if used in conjunction with additional information (specially provided new landmarks or compass bearings) can enable independent mobility in areas which would normally be avoided by blind pedestrians.

TRANSMISSION OF MOBILITY INFORMATION THROUGH THE SKIN

We have continued to monitor the progress of the research group at the Smith-Kettlewell Institute of Visual Sciences in San Francisco where an attempt is being made to use patterned tactual stimulation for the purpose of transmitting environmental information by non-visual means. We have also kept in touch with research on the Optacon reading aid developed by a team at the Stanford Research

Institute. Our own experiments have determined the two-point thresholds using the same type of stimulation used by the two devices (vibrating stimuli at 60 and 250 Hz). Results show conclusively that differences in both two-point thresholds of the two surfaces alone will account for the comparative success of the Optacon. This suggests that the back, or any other part of the torso, would not be a suitable site for the tactual display of a visual prosthesis intended for the transmission of detailed information.

DEVELOPMENT OF AN ULTRASONIC OBSTACLE DETECTOR

A small ultrasonic obstacle detector, which signals target range by means of a very simple auditory display, has now been developed. We anticipate that the obstacle detector is likely to be of considerable use as a secondary aid for long cane users and guide dog owners. It should be especially valuable as a means of locating landmarks positioned some distance from the main travel path. The partially sighted and low-vision blind, many of whom are unable to discriminate solid obstacles from shadows under adverse lighting conditions, might also rely on the device to establish a clear path.

MEASUREMENT OF ADJUSTMENT TO BLINDNESS

Guide dog owners commonly claim that guide dog training brings about beneficial changes in life style and a feeling of improved status within the community.

We have attempted to confirm these claims by monitoring the change in self-esteem of fifty blind people resulting from guide dog training and subsequent independent mobility with the dog.

Although this study has been concerned with the effects of guide dog training, the measure of self-esteem is independent of the form of training or rehabilitation which the subject undergoes. We are now applying the same measurement techniques to the social rehabilitation programs currently available for the visually handicapped so that the efficacy of these programs might be established.

PROBLEMS OF LOW-VISION BLIND

Attempts are being made to establish a working relationship with one of the eye hospitals in our local area with the aim of evolving a combined clinical/performance assessment procedure for the low-vision blind. Information is also being collated on the various low-vision training programs which have been set up in other parts of the world.

THE DEVELOPMENT OF AN INEXPENSIVE VACUUM FORMING MACHINE

Although our publication on the design and production of maps for the visually handicapped has done much to encourage amateur map makers, the lack of availability of vacuum forming facilities, required for the production of plastic tactual maps, tends to slow down their progress.

Because commercially available vacuum forming machines are usually very expensive (£150-£300), we are examining the possibility of making the designs for a "do-it-yourself" machine available to interested parties. An effective prototype machine, which should cost less than £50 to build, has been produced in our workshops.

THE PROVISION OF IN-SERVICE TRAINING

Periodically we organize and run in-service training sessions for mobility officers. In the past, courses on the use and training of the sonic aid have been provided and in the near future a series of courses on the design and production of maps, and on how to teach their use, are being organized.

At the same time, individual members of the research group contribute to the various technical training programs offered by the North Regional Association for the Blind and the Southern Regional Association for the Blind.

PUBLICATIONS

Because our current research contract has been running for only eighteen months much of the work carried out so far has not yet been published. The following list of publications is divided into those papers which have appeared during the course of the contract, and those which have been submitted or are in preparation.

Papers published since 1971:

Armstrong, J. D. Evaluation of mobility aids. Proceedings of a Conference on the Evaluation of Sensory Aids for the Visually Handicapped (Ed. Guttman), pp. 101-04. National Academy of Sciences, Washington, 1972a.

Armstrong, J. D. The adding of visual information to previously recorded video-tapes: A functioning system. *Quarterly Journal of Experimental Psychology*, 1972b, 24, 361-63.

Armstrong, J. D. The design and production of maps for the visually handicapped. *Mobility Monograph No. 1*. Department of Psychology, University of Nottingham, 50 pp. 1973.

Armstrong, J. D. Mobility problems: A review of methods and aids. Report on European Conference for Technical Aids for the Visually Handicapped. Handikappinstitutet, Stockholm, 1974.

Gazely, D. J. Communication and mobility training with hearing impaired clients. *New Beacon*, 1973, LVII, 160-75.

Gill, J. M. & James, G. A. A study on the discriminability of tactual point symbols. *Research Bulletin No. 26*, American Foundation for the Blind, 19-34, 1974a.

Gill, J. M. & James, G. A. Mobility maps: The choice of symbols. *New Beacon*, 1974b, LVIII, 35-38.

Heyes, A. D. A versatile ultrasonic mobility aid for research purposes. Proceedings of Leonard Conference on Research into Visual Handicaps. 3-5 January 1972. Southern Regional Association for the Blind, 1972.

James, G. A. Problems in the standardization of designs and symbolization in tactile maps for the blind. *New Beacon*, 1972, LVI, 87-91.

James, G. A., Armstrong, J. D., & Campbell, D. W. Verbal instructions used by mobility teachers to give navigational directions to their clients. *New Beacon*, 1973, LVII, 86-91.

James, G. A., & Armstrong, J. D. An evaluation of the "Silva" braille compass: 1. Static tests. *New Beacon*, 1974, LVIII, 225-29.

James, G. A., Campbell, D. W., & Armstrong, J. D. An evaluation of the "Silva" braille compass: 2. Field trials. *New Beacon*, 1974, LVIII, 253-55.

Leonard, J. A. Studies in blind mobility. *Applied Ergonomics*, 1972, 37-46.

Leonard, J. A. The evaluation of blind mobility. *Research Bulletin No. 26*. American Foundation for the Blind, 73-76, 1973.

AN ELECTROMECHANICAL NUMERIC BRAILLE DISPLAY*

A Familiar Tactile Representation of Electrically Encoded Digital Signals

George F. Dalrymple**

Summary: A simple electromechanical numeric braille display has been developed and implemented. One such system is now in use at a broadcast station. It enables an otherwise qualified blind person to meet the restrictions placed on his first class radio telephone license by the Federal Communication Commission.

This device can be interfaced with almost any electronic instrument with digital binary coded decimal (BCD) outputs. It can make electronic instrumentation with visual digital displays also available to the blind.

This concept can be extended to modules that display the full braille cell. Such modules can be used in systems to give the blind almost equal access to the data presented displayed on video communication terminals as enjoyed by the sighted.

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The blind who want to work in modern technological based jobs instead of the more traditional jobs have still another disadvantage; namely, much of the information which they must use in their work is available only either as digital encoded or analog electrical signals.

How can the blind use these electrical signals or make the required measurements? The moving-pointer analog meter can be tactually read if the glass face is removed, a braille scale added, and the user has a very delicate touch so as not to damage the meter.[1] This technique is not usable if the meter is delicate (as is most generally the case), if dangerous voltages exist in the meter, or if the signal is in digital form. Another analog meter available to the blind is the Servo Meter[2] (American Foundation for the Blind). This device has a braille marked six inch (diameter) dial that the user reads. The dial is attached to a potentiometer and it is driven by a motor. Internal circuitry measures the difference between the input voltage and the potentiometer voltage which is proportional to shaft rotation. The Servo voltmeter uses this signal to drive the motor in such a way as to reduce this difference to zero. This meter solves the difficulties of the moving pointer meters except that only an analog voltage can be used.

The trend at the present time in engineering is towards digital data

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**Acting Director, Massachusetts Institute of Technology, Sensory Aids Evaluation and Development Center.

with analog indicators primarily reserved for certain applications where they are superior; e.g. matching two values, etc.

There are many ways to present digital data with tactile representation. Several different solenoid-operated single braille cells have been developed. All of those known to the author contain either one or two cells or have much larger than standard dimensions.[3,4] If additional braille cells are required, then they must be in widely separated groups of one or two cells.

A line of ten pneumatically operated braille cells has also been demonstrated.[5] Each cell is a complete replaceable assembly and includes a solenoid operated latch. When the latch is energized, plungers for all dots in that cell are free to move, according to the pressure in the pneumatic control line for that dot. There are six pneumatic control valves that cause either a slight over pressure or a slight vacuum to be on its associated control line when the data in a selected cell is to be changed. The demonstrator including a keyboard was packaged in an attache case and was powered by internal rechargeable batteries.

There have been other tactile digital displays developed. One consists of a matrix of solenoid actuated pins arranged in a matrix of four rows and as many columns as digits.[6,7] The data is presented in Binary Coded Decimal (BCD) form. The top row represents ones, the second row represents twos, the third row represents fours and the fourth row represents eights. Thus to read the display, each pin must be sensed and the necessary addition to determine the value of the digit displayed must be performed by the user.

The display presented here is a braille display. Each braille cell corresponds to a digit and conventional braille patterns are used to represent the numbers. Since only the four dots per cell are required to give the braille number patterns, only four are implemented. The braille cell dimensions used are those used in the Perkins braillewriter. The only difference between this display and conventional braille is that metal surfaces instead of paper surfaces are used.

The braille display is composed of modules, each containing two cells. It is necessary to make dual cell modules, as the smallest solenoids with both adequate force characteristics and sufficiently high reliability are 7/16 inch in diameter. This allows the solenoids to be mounted on 1/2 inch centers, twice the pitch of standard braille cells. Smaller solenoids could be used but those available have not demonstrated sufficiently high reliability for this use. These modules can then be stacked to form a line of electrically controlled braille numbers of any desired length.

The module, shown in Figure 1, consists of a head or pin guide which positions the movable pins in the braille matrix. Each pin protrudes through the head when its corresponding solenoid is energized such that the pin can be felt. The head structure also contains springs that hold down the individual pins below the reading surface when the associated solenoid is not energized. The head is attached to a solenoid frame or main support. Each pin is connected to or controlled by a lever that serves as a connecting link with its appropriate solenoid. These levers are arranged in two vertical layers to prevent mechanical interference.

The head can also contain a latch arrangement for holding the braille pattern without expending power in the main solenoids supporting the pins. The latch can be controlled by either two solenoids; i.e. one solenoid for each cell, or a single solenoid for both cells of the module. The latch has not been demonstrated.

The display can be operated directly through suitable drivers and code translators from the BCD outputs or most digital electronic instruments. The first display used 4 SSI (Small Scale Integration), TTL (Transistor-Transistor Logic) integrated circuits and 4 Darlington transistors to drive each cell. The BCD data source, an Analogic Digital Panel Meter, was incorporated into the package both to keep the lead lengths short and to make the braille meter a complete unit.

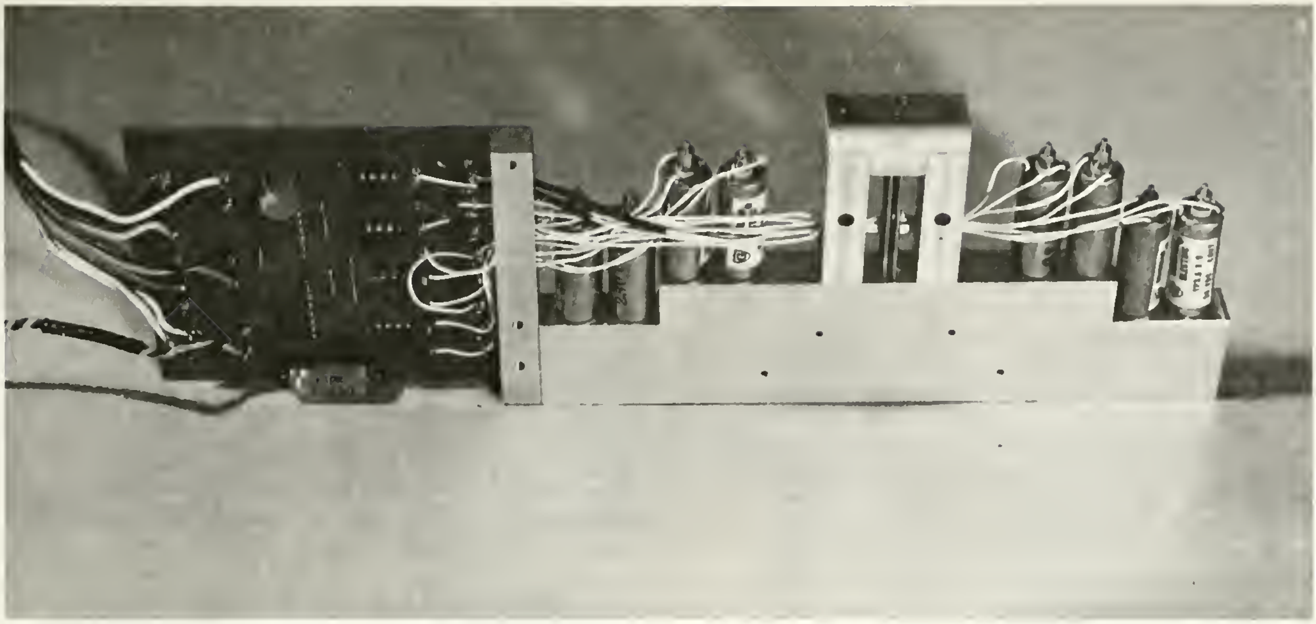

Figure 1. Output Module, Including Solenoid Drivers

The next numeric braille display, shown in Figure 2, was made to be used with the metering equipment of a Continental Electronics 5 KW broadcast transmitter at an Englewood, Colorado station. The display is located on the top of the cabinet at the left of Figure 2. The controls, on the front of the cabinet, are a mode switch and the power switch. When the mode switch is up, the braille display follows the visual display of the meter. In the down position the mode switch causes the meter to hold its present reading and the braille cells to display that value. The mode switch is a center off, locking up and momentary down switch. To hold the system the mode switch must be held down.

It was not feasible to mount the braille display within the metering rack of the transmitter, but the display is such that it could be set on a shelf on the front of the rack.

Figure 2. Complete System Including the Numeric Braille Display, Multiplexer Encoder, and Digital Panel Meter.

A multiplexer system was built both to reduce to six the number of wires necessary between the display and the meter from the 19 wires that would otherwise be necessary. With the multiplexer four line drivers are needed instead of the seventeen that would be needed with direct connections. The multiplexer is the card on the right of Figure 2.

The multiplexer has a further advantage in that the decimal point can be inserted at the correct location and moved by a simple logic signal. This feature is not in the unit at the broadcast station. The engineer had to devise a braille table listing the location of the decimal point and the electrical units measured versus the meter function select switch position.

There are two other peculiarities with this particular unit. Since the meter is a 3 1/2 digit meter, the most significant digit is either a zero or one. Further the meter measures both negative and positive voltages. To indicate a negative input signal the multiplexer adds two to the most significant digit. If the tactile display indicates 2abc or 3xyz the correct value is -0abc or -1xyz.

The meter also has an over-range indication. Visually it is shown by a +1 or -1 with the trailing digits blanked. The multiplexer adds four to the most significant digit when this condition is encountered. The resulting display when the input is out of the meter's range is either 5000 or 7000 depending on whether the signal is positive or negative.

The latest unit is very similar to its immediate predecessor. A third output module is used such that four digits and a decimal point can be displayed. Since all digits are the same, the decimal point location is determined by the multiplexer encoder. Logic in the encoder places the decimal point in its proper location in the data stream.

This type of digital braille display can be used for any numeric application. For example, it is planned to connect five of these modules (10 braille cells) to an 8-digit four-function calculator. This calculation will have both a visual seven-segment display and a tactile four-dot braille display.

This braille module concept can be extended to a system with a full braille cell; i.e. 6 dots per cell. A line of alphanumeric braille cells can then be interfaced with a "soft copy"; i.e. video terminal, and provide the blind user essentially the same access to the data that a sighted person has. Since only one or two lines of most of the video display can be displayed tactually at a time, a selector switch must be included so that the user can determine simply and rapidly which lines are available to him.

ACKNOWLEDGEMENT

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REFERENCES

1. Wexler, A. *Experimental Science for the Blind.* New York: Pergamon Press Inc., 1961.
2. "Servo-Voltmeter," *Aids and Appliances.* American Foundation for the Blind, New York, 18th Ed., p. 39.
3. Mick, D. E., Hittinger, G. N., "An Inexpensive, Universal Braille (Unibrl) Output Device," Air Force Weapons Laboratory, Albuquerque, New Mexico, July 1969.
4. Fieldgate, I. O. "Reading Machine for the Blind," U.S. Patent 3, 395,247, July 30, 1968.
5. Sutherland, N. B. "Development of a Dynamic Braille Display," MITRE Corporation, MTR-1951, Sept. 1970.
6. Cranmer, T. "Braille Display for Electronic Calculators," Patent Application 1974.
7. "Position Feelout System," Elm Systems, Inc., *American Machinist*, June 1973, 1. 49.

THE AUTO-COM AT KENNEDY MEMORIAL HOSPITAL [1]

Rapid and Accurate Communication by a Non-Verbal Multi-Handicapped Student

George F. Dalrymple[2]
Ann Bullock[3]
Janice M. Danca[4]

The Auto-Com is a device to enable those with severe motor impairment, e.g. cerebral palsy, to communicate with others effectively. The device was developed by the Cerebral Palsy Communication group of the University of Wisconsin. A student at the Kennedy Memorial Hospital Day School is now using the Auto-Com in her classroom.

INTRODUCTION

An Auto-Com is being used by a ten year old Kennedy Memorial Hospital Day School student, Laura, who has severe cerebral palsy. Although Laura is unable to speak, the Auto-Com provides her with meaningful communication. The Auto-Com has increased her communication rate and accuracy over that obtained using a vertically-mounted guarded keyboard electric typewriter.

The Auto-Com was developed at the Cerebral Palsy Communication Group of the University of Wisconsin-Madison. The Auto-Com can be visualized as an extension of the conventional letter board. With the letter board a user points to a letter until a monitoring person understands that the letter under the pointer is the desired letter and records it. The Auto-Com replaces the monitoring person by a display and control electronics.

DESCRIPTION OF AUTO-COM

The board consists of 84 brightly colored squares on a plastic covered working surface. Each of the squares has a character painted on it. The user moves a pointer to the desired character and holds the pointer over the square. After a short, though adjustable period of time, the Auto-Com responds and sends the selected character to the output display device. The output device on the unit used at Kennedy is a video terminal employing a commercial character generator and a TV monitor.

Magnetic reed switches are used as the sensors. The pointer contains a small magnet that operates the reed switches. The most common pointer has been a plexiglass slider with a molded handpiece and a magnet mounted on it. A velcro strap is used to secure the slider to the hand of the user who is incapable of grasping

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[1]Paper originally appeared in R. Foulds, & B. Lund (Eds.) *Proceedings of the 1974 Conference on Engineering Devices in Rehabilitation.* Boston, Mass.: New England Medical Center Hospital, 1974.

[2]Acting Director, MIT, Sensory Aids Evaluation and Development Center.

[3]OTR, Kennedy Memorial Hospital, Occupational Therapy Department.

[4]Teacher, Kennedy Memorial Hospital Day School.

the slider. The magnet is positioned sufficiently far away from the grip so that the selected square is visible through the slider to the user. Small strips of felt are secured to the underside to reduce the effort needed to move the slider. Laura cannot use a slider due to severe spasticity in her upper extremities. She operates the Auto-Com with a felt covered magnet placed on the tip of her head pointer.

The Auto-Com monitors the position of the magnet at all times but does not respond until the magnet is held within the general proximity of a character for a short, adjustable length of time. Thus the user has time to move the magnet if it is over the wrong character before the Auto-Com responds. A red light at the top of the board is illuminated when a sensor switch is closed and the time delay is operating. When the character transfer occurs, a green light is turned on and a click is sounded.

There are several control characters available: carriage return; space; cursor up, down, left or right; home; and clear. The "home" character returns the cursor to the upper left hand position of the screen. The "clear" character erases the screen and returns the cursor to the home position. There is a significantly longer time delay associated with clear character to prevent accidental clearing of the screen. The red switch-closed light also flashes during the clear time delay previous to clearing as a warning that you are about to erase the screen.

DESCRIPTION OF THE PROBLEM

Working and interacting with nonverbal severely physically handicapped children has revealed a need for an objective understanding and evaluation of their knowledge and thought processes. Until now communication by nonverbal cerebral palsy students has involved a variety of methods--from a simple yes/no response to a pointing response by hand, foot, or head while using a communication board to typing with a modified typewriter. Through these methods we have attempted to evaluate and encourage success and independence in the areas of cognitive skills, receptive and expressive language, and visual perceptual skills.

Unfortunately, the successful function of these devices and methods are often impeded by the interference of motor incoordination, awkward positioning of the device and a confusion of the user's exact response. As a result, you only have a "feeling" or vague idea that the child is alert and intelligent but you have no effective means of knowing the degree and level of understanding by the child. Most important is that the children have a limited means of communication, expression, and interaction with their environment.

TRAINING

The Auto-Com has helped solve most of these problems. Initially, the Auto-Com was located in a small room for training individual children. It had three purposes: 1) training for nonverbal severely involved cerebral palsy children; 2) diagnostic evaluation of traumatic physically involved patients; and 3) motivation and training of children with learning disabilities. Initially, two cerebral palsied children were trained. One used the hand slider and the other the head pointer. The second child, Laura, was chosen to use the Auto-Com in the school situation because of the severe degree of her handicap, her high motivation to learn and her speed in mastering the equipment.

Previously Laura had used a vertically mounted guarded keyboard electric typewriter. Her training on the Auto-Com progressed in the following order: location of letters--numbers--her name--carriage return (CR)--names of her brothers and sisters--correction via back spacing--copying words (days of the week)--answering yes/no or multiple choice questions--independent words--speed tests--reading tests and mechanics of addition with correct signs.

The correction capabilities of video display of the Auto-Com has helped determine the cause of many of the errors which she made while using the typewriter. Her limited control abilities had prevented her

from correcting all the mistakes she made. Now she has the ability to correct any mistake she recognizes as a mistake. Hence any errors remaining when she has completed writing using the Auto-Com is a genuine error, not one caused by her limited motor capabilities.

After she had learned to use all of the functions of the Auto-Com while using it in a structured setting, it was decided that she should use it in a more purposeful functional setting--the classroom.

CLASSROOM PERFORMANCE

Laura has attended Kennedy Memorial Hopsital for Children Day School for the past four academic years. She is an alert and curious child who enjoys group situations and is well accepted by her peers. Her prior training with a head pointer allows her to be involved in pleasurable activities such as painting and coloring; yet this did not address her real problem--communication. Her severe physical limitations present difficult and at times, impossible situations for her performance in academic tasks and social activities; e.g., many other children with severe motor problems can develop a pencil grasp or alternative methods.

With the sensitivity of a child, Laura began to feel the impact of these limitations and demonstrated a low level of frustration. This was particularly evident when she was unable to make a response (other than yes/no) to a question or to express a feeling to her classmates and teachers. This child is now ten years old and any frustration that is now evident will certainly increase with the approach of adolescence. While Laura always appeared to be an alert child, it wasn't possible to determine her real potential in the areas of reading, arithmetic and language skills. When training on the typewriter began, however, her therapists and teachers began to suspect that Laura had a high retention level and intellectual potential.

The electric typewriter which was used with the head pointer seemed the most productive solution to pursue this potential. However, it did present many problems: 1) it tended to isolate Laura from the rest of the class. She would always be working on a different task than her peers as she was unable to work on paper-oriented tasks. 2) The typewriter was non-corrective which increased her level of frustration. 3) The keys were too small and spaced too closely to each other. There was a high level of error due to Laura's spasticity.

When the Auto-Com was introduced, it opened a wide diversity of academic and social activities for Laura. We were able to document how her excellent visual and auditory receptive memory had given her a large sight vocabulary (mostly three-letter nouns, color words, days of the week, number words, and a few descriptive adjectives). From these words she has been able to build and is now at the level of structuring simple sentences.

Laura has become a more involved member of the class with the Auto-Com. She gives the children simple greetings in the morning since she quickly learned how to write each child's name.

When an activity involves a worksheet, Laura can now participate. It is no longer necessary to provide a different activity for her as class worksheets are adapted for her use. Also, her work can be checked from a distance by simply reading the screen. The Auto-Com has assisted the reading clinician in covering a greater amount of material since Laura can respond spontaneously to questions asked. A phonics program has been started for Laura with excellent results.

As her dependence on teacher and classmates has lessened with the use of the Auto-Com, Laura has become a more self-confident child. She can be given a task and work on it independently without interruption and increasingly without assistance from the teacher. This has generally given Laura a better self-image which has very obviously affected her total personality. The Auto-Com has been the most helpful in giving us substantial evidence of her abilities. With this information, we have been able to set some realistic academic

objectives and precise goals for Laura. The teacher and clinicians now have a clearer understanding of her capabilities and comprehension of all academic skills.

ACKNOWLEDGEMENT

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REFERENCES

Vanderheiden, G. C., Lamers, D., Volk, A. M., & Geisler, C. D. *A new means of communication for the severely handicapped: The auto-monitoring communication board (Auto-Com).* (Abstract) Fourth Annual Meeting BioMedical Engineering Society, January 29-30, 1973.

Vanderheiden, G. C., Volk, A. M., & Geisler, C. D. *The auto-monitoring technique and its application in the auto-monitoring communication board (Auto-Com): A new communication aid for the severely handicapped.* Carnahan Conference on Electronic Prosthetics, University of Kentucky, Lexington, Kentucky, 1973, pp. 47-51.

Vanderheiden, G. C., Volk, A. M., & Geisler, C. D. *An alternate interface to computers for the physically handicapped: The auto-monitoring communication board (Auto-Com),* 1973 National Computer Conference. (In press.)

REPORT OF THE PERCEPTUAL ALTERNATIVES LABORATORY FOR THE PERIOD JULY 1973 — JUNE 1974

Emerson Foulke*

Perception is the process of acquiring information by searching for and interpreting sensory stimulation. When the functioning of a sensory, cognitive, or motor component of a perceptual system is impaired, the affected individual must find another way of acquiring functionally equivalent information; he must develop a perceptual alternative. On June 25, 1969, by an action of the Board of Trustees of the University of Louisville, the Perceptual Alternatives Laboratory was established, under the auspices of the Graduate School of the University of Louisville, for the purpose of investigating perceptual alternatives. At its present stage of development, the research program of the Perceptual Alternatives Laboratory is concerned primarily with the investigation of perceptual alternatives for individuals with visual impairment. However, perceptual alternatives for visually unimpaired children with severe reading problems and for children with profound motor disabilities are also receiving attention, and the long-range objective of the laboratory is to investigate the entire spectrum of useful perceptual alternatives.

The laboratory's program of research has received support from three external sources during the year covered in this report. On October 1, 1972, the laboratory received a grant of $25,000 from the Robert Sterling Clark Foundation, and the first three months of the current fiscal year were included within the period for which support was provided by funds from the Clark Foundation. During the last nine months of the current fiscal year, the laboratory's program of research has received support from a grant of $75,000, awarded by the Grant Foundation. Support from this grant will continue throughout the fiscal year ending June 30, 1975. The Perceptual Alternatives Laboratory, in collaboration with Ada-Max, an audiovisual engineering firm in Jackson, Michigan, is investigating techniques for the retrieval of information from tape recorded texts, and this investigation is receiving support from a grant of $15,582.96, awarded to the Perceptual Alternatives Laboratory by the Seeing Eye Foundation, Incorporated.

I have applied to the National Institutes of Health for a grant of $66,911 to support a program of research in which the objectives are to determine, through basic perceptual research, the requirements that must be satisfied by devices intended to aid low vision, to use those requirements as guidelines in designing and constructing a family of low vision aids, and to evaluate the effectiveness of the aids that are constructed in field tests involving members of the population for which they are intended. If this application is successful, it will provide support for a three year period beginning January 1, 1975. The proposed research will be undertaken in collaboration with Dr. Paul Jones, a member of the Psychology Department at the

*Director, Perceptual Alternatives Laboratory, University of Louisville, Louisville, Kentucky.

University of Louisville, and Mr. J. Malvern Benjamin, President of Bionic Instruments, Incorporated, Bala Cynwyd, Pennsylvania.

ACQUIRING INFORMATION BY LISTENING

The information that is ordinarily acquired by reading the printed page can also be acquired by listening to the recorded oral reading of another person. Though reading by listening is not as effective as the visual reading of a skilled reader, there are circumstances under which it may be a desirable alternative to visual reading. The busy physician or executive may make better use of the time he spends in his car by listening to recorded oral reading as he drives. The skilled worker may be aided in carrying out a complicated assembly requiring continuous visual monitoring by listening to a sequence of recorded oral instructions. The child with normal vision who does not learn to read effectively, and who is not aided by efforts of remediation, may find reading by listening the most viable alternative. Reading by listening is an obvious alternative for those who have little or no vision, and under many circumstances, it offers a better alternative than braille or large print. The investigation of reading by listening is a major component of the laboratory's program of research. This investigation includes research intended to explicate the processes on which reading by listening depends, and research to evaluate a variety of methods and instruments intended to facilitate reading by listening.

The Comparative Evaluation of Simple Index-Codes for the Identification of Locations in Tape-Recorded Texts

A serious problem experienced by those who read by listening to tape-recorded texts is the difficulty of finding specific locations, such as chapter headings, paragraph headings, or the locations at which new pages begin in the inkprint analogs of such texts. Because these locations cannot be found easily in tape-recorded texts, the retrieval of desired information is an inefficient process, and as a consequence, tape-recorded texts are less effective than their inkprint analogs.

The retrieval problem may be reduced by recording, at appropriate locations in the track on which text is recorded, tones so low in frequency that they are nearly inaudible. Because they are nearly inaudible when the tape is reproduced at the normal playback speed, their presence does not interfere with the perception of speech that has been recorded on the same track. When the tape is played back in the fast forward mode on a tape recorder that has been modified so that the tape remains in contact with the playback head during fast forward operation, the tones are increased in frequency by an amount that is proportional to the increase in tape speed, and they are heard as clearly audible beeps, displayed against the background of high-pitched chatter that results from reproducing speech at the fast-forward tape speed. This system of indexing is currently employed by Recording for the Blind in its preparation of recorded textbooks. A rudimentary code with two characters is used. One character, a single beep, signifies the beginning of a new page. The other character, two consecutive beeps, signifies the beginning of a new chapter. An announcement at the beginning of each track indicates the pages covered on that track, and if a new chapter starts on the track, this fact is also announced. With this information, the reader can, by interpreting code characters that are manifest during fast forward operation, locate pages and chapters in which he is interested.

An index code with a larger number of code characters should permit a more detailed search of a tape-recorded text and the result should be more efficient retrieval. Accordingly, a project was initiated in collaboration with the American Printing House for the Blind to investigate the feasibility of an expanded index code. The objectives of this project are to develop a code that appears to be suitable for indexing purposes, to demonstrate that it can be learned and used for retrieval of information by blind students, and to conduct more extended field tests in which blind students are given the

opportunity to use tape-recorded texts that have been indexed with the characters in the code.

The selection of a code. Tones produced by an audio-frequency oscillator were used to compose code characters because their generation is a simple matter, because they can be recorded satisfactorily, and because they can be varied in several dimensions in which human observers demonstrate good discrimination. Six elements for use in composing code characters were realized by varying the signal produced by the oscillator in three dimensions. This signal could have either of two durations, either of two frequencies, and it could exhibit either of two portamento effects--a tone that increases in frequency during its course, and a tone that decreases in frequency during its course. Using these elements, five codes were constructed and subjected to comparative evaluation. Each code had six characters, and each character was composed with either one or two elements. The elements used in composing the characters in the first code were long and short tones, or dots and dashes. The elements used in composing the characters in the second code were low and high-pitched tones. The two portamento effects were used to compose the characters in the third code. The dimensions used in the first two codes were combined to form the characters in the fourth code. The dimensions used in the first three codes were combined to form the characters in the fifth code. When only one dimension was used in composing characters, a total of six characters could be formed. However, combining dimensions increased the supply of possible characters, and so the characters used in the fourth and fifth codes were chosen by drawing six characters at random from the supply of possible characters.

The five codes identified in this manner were taught to five comparable groups of subjects drawn from Introductory Psychology classes at the University of Louisville. Each group contained 20 members. Numbers were used to name code characters, and a paired-associates method was employed for code learning. A learning trial consisted of one randomly permuted presentation of the six-code characters. A subject heard a code character, and four seconds later, its name was pronounced. After another two seconds, he heard the second character and so on, until all six characters had been presented. On the second trial, the subject was instructed to guess the name of each character during the interval between its presentation and the pronunciation of its name. Learning trials were administered to each subject until he met a criterion of two consecutive errorless trials.

The results of this experiment are summarized in Fig. 1. This figure is a graph with five curves, one for each of the five codes. The scale values on the x-axis are trial numbers. The scale on the y-axis indicates the number of subjects to whom a given trial was administered. The height of a curve above any given trial number on the x-axis is a function of the number of subjects to whom that trial was administered. Since all subjects received the first trial, all five curves start at 20 on the y-axis. However, as the subjects learning a given code reached criterion, its curve gradually falls, and reaches the x-axis when all 20 subjects have met criterion. By comparing the five curves, the impression is strong that the first code was much more easily learned than the remaining four codes, and this impression was confirmed by an analysis of the variance of code learning scores. Consequently, the first code, the one in which elements of two durations were used for the composition of code characters, was selected for further evaluation.

Search and retrieval. An experiment has been planned to evaluate the efficiency with which blind school children can find locations in recorded tapes that are indexed by code characters. A junior high school history book was chosen for use in the experiment, and an outline was prepared which reflects the organization of that book. The book that was chosen contains units that are divided into chapters. Each chapter is further divided into subsections. Each unit includes a section called "Unit Activities," and each chapter includes a section called "Reviewing the Essentials." The locations at which these five text components begin, and the locations at which new pages begin

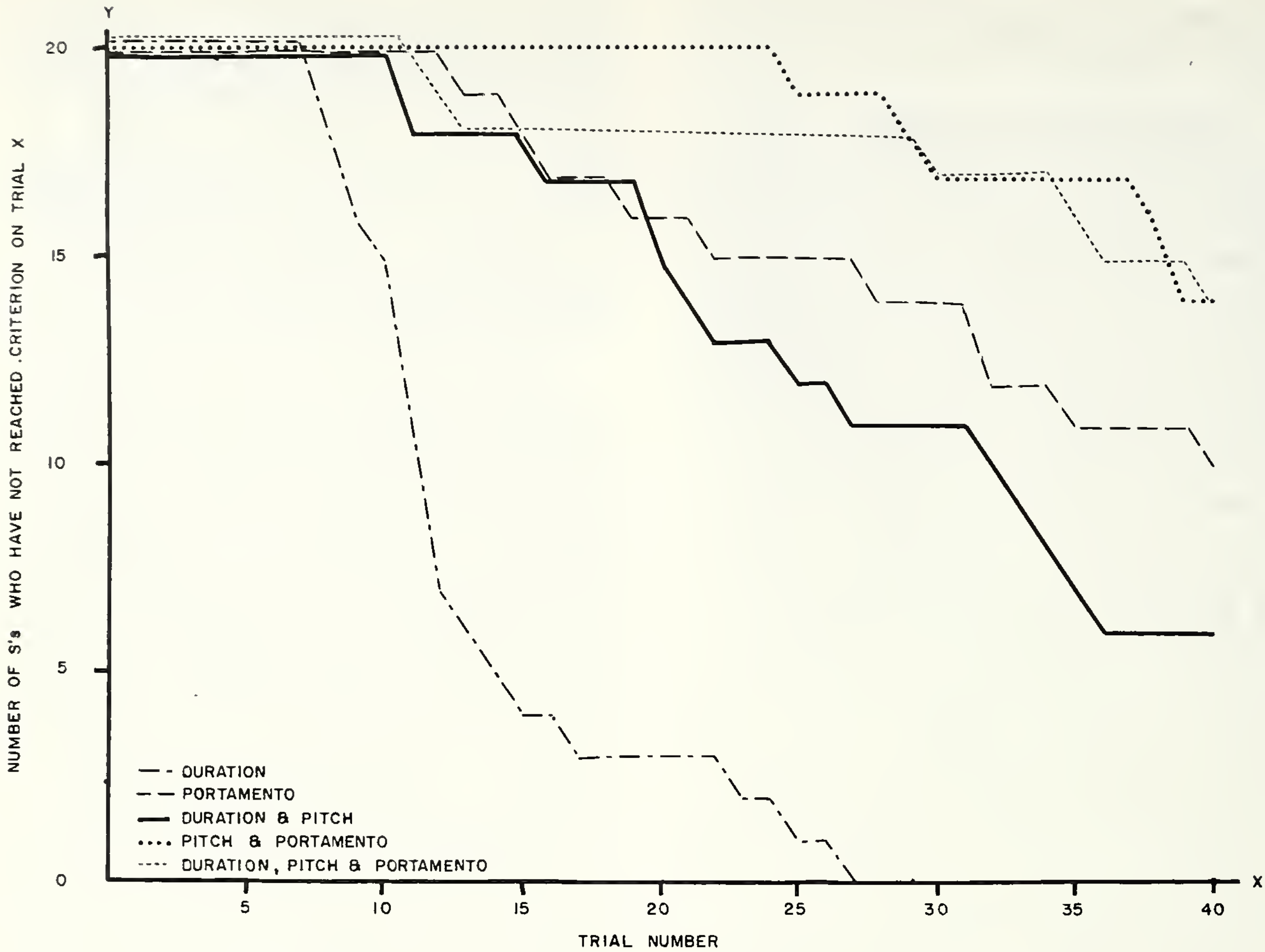


Figure 1. Ease of Learning Five Index Codes

are the six locations that are marked by the six characters in the code. We prepared two outlines in which these components are identified. Each outline includes a couple of units and several chapters. The announcements of outline components were then recorded on tape at 20-second intervals. The code characters that identity the announcements of text components were generated by an oscillator, switched on and off by an electronic switch controlled by a battery of decade interval timers. The oscillator was set for a frequency of 50 Hz. The timers were adjusted so that the duration of short tones (dots) was 0.5 seconds, the duration of long tones (dashes) was two seconds, and the intervals separating elements within a character were two seconds. Using the source tape and the apparatus for generating code characters, the announcements of text components and the appropriate code characters were mixed and recorded on a final master tape. Cassette duplicates of master tapes were then prepared for use in the experiment. These casettes will be reproduced on the cassette recorders sold by the American Printing House for the Blind. These recorders have been modified so that the playback head is not retracted from the cassette during fast-forward and fast-rewind operation, thus allowing it to scan the tape during these modes of operation. When a cassette containing the indexed outline is played on one of these recorders at the normal playing speed of 1-7/8 inches-per-second, the announcements of text components are heard at 20 second intervals. Of course, the code signals that identify these announcements are also reproduced, but since their frequency is quite low, and since the low-frequency response of the cassette recorders on which they are

reproduced is not very good, they are nearly inaudible. When a cassette is reproduced at the fast forward tape speed (although this tape speed varies, depending upon the amount of tape that has been wound from the supply hub onto the takeup hub, it is in the neighborhood of 30 inches-per-second) code characters are clearly audible against the background of high-pitched chatter that results from reproducing the announcements of text components at the fast forward speed. At this tape speed, the frequency of the tones used in composing code characters is approximately 800 Hz. Short tones have a duration of approximately 30 milliseconds, and long tones have a duration of approximately 125 milliseconds. The intervals separating elements within characters are also approximately 125 milliseconds.

Two of the code characters used in preparing these cassettes, the one with a short tone followed by a long tone and the one with a long tone followed by a short tone, are not symmetrical, and they are therefore altered by reproduction in the fast-rewind mode of operation. Preliminary experience strongly indicated the desirability of code characters that would be reproduced properly in either the fast-forward or fast-rewind mode of operation. Accordingly, two symmetrical characters with three elements-per-character (short-long-short and long-short-long) were substituted for the two asymmetrical characters, and new tapes were prepared. These tapes appear to be quite suitable for use in the experiment that is planned.

In this experiment, students in grades 4 through 12 at the Kentucky School for the Blind will learn the index code. The procedure will be the same as the one employed in the experiment that was conducted in order to select the code, but code characters will be associated with the announcements of text components instead of with numbers. They will then receive training in the use of code characters to find locations in one of the recorded and indexed outlines. Upon the completion of training, the other recorded and indexed outline will be employed in a test of the speed and accuracy with which subjects can locate text components. If the results of this experiment indicate that the use of the index code enables effective and efficient retrieval, it will be used to index tape-recorded texts. These texts will be read by subjects who are given tasks requiring search and retrieval, and the efficiency with which they perform those tasks will be compared with the efficiency that characterizes the performance of such tasks when conventionally recorded texts are used.

Other indexing schemes. Two alternative indexing schemes are also under consideration. In one approach, instead of using code signals, the actual announcements of text components will be recorded at 30 inches-per-second, reproduced at 1-7/8 inches-per-second, and imposed on the full text recording at the appropriate locations. When a tape prepared in this manner is reproduced at the playback speed that is proper for the full text recording, the announcements will be heard as very low-pitched background noise. When the tape is reproduced in the fast-forward mode of operation, the announcements will be heard at approximately the correct pitch and displayed against the background of high-pitched chatter that results from reproducing the full text in the fast-forward mode of operation. In the other alternative approach, the feasibility of the Zimdex method of locating text components will be examined. According to this method, full text is recorded on the first track of the cassette. On the second track, consecutive numbers are pronounced at a constant rate. The numbers are pronounced in reverse order, and a starting number is chosen that will permit the pronouncer to arrive at the number "1" just as the second track is coming to an end. Numbers are read in reverse order so that number "1" will be adjacent to the beginning of track one. Track one is then played, and at each location that is to be indexed, the cassette is turned over and the Zimdex number recorded on track two at that point is determined. If the location to be indexed falls between two Zimdex numbers, the higher of the two numbers is used. A written chart is prepared in which a Zimdex number is assigned to each of the locations that is to be indexed. The person using this method consults the chart

to determine the Zimdex number associated with the location he wishes to find. He then searches track two of the cassette until he finds that number, and by turning the cassette over at that point, he is assured of being very close to the location for which he is searching.

The method just described is suitable for use on any conventional cassette recorder. If a cassette recorder is modified by replacing the half-track playback head with a quarter-track stereo head and a two position switch for choosing the quarter-track that is to be reproduced, a variant of the method becomes possible that may prove to be more convenient. The full text is recorded on one-quarter track, and the Zimdex numbers, now pronounced in forward order, are recorded on the parallel quarter-track. As before, a chart showing the assignment of Zimdex numbers to text locations is prepared. Using the appropriate switch setting, the user searches the second quarter-track until he finds the Zimdex number that marks the text component for which he is searching. Then, simply by operating the track selector switch, and without even having to stop the cassette transport, he finds himself listening to the full text track at a point that is very near the location for which he is searching.

Both the Zimdex method and the method in which actual announcements are used to mark text components are under investigation at the present time. We expect that all of the indexing schemes described in this section will prove to be useful, and our intention is to define the characteristics under which each is most useful.

The Absolute Identification of Tonal Dyads

In last year's report, an account was given of an experiment that was conducted to evaluate the feasibility of the dyads in the touch tone code used by the telephone company as indicators of the values registered on digital displays, such as those found on electronic calculators. The apparatus required for the generation of these dyads is small, readily available, and relatively inexpensive. The electronic logic required to interface this apparatus with devices that display their results digitally is well known and easily provided. However, in addition to its feasibility from an engineering point of view, a display must also be perceptually feasible. This means, in the present case, that it must be possible for human observers to make absolute identifications of the dyads in the touch tone code with sufficient speed and accuracy to warrant their use as code signals in situations in which there is little tolerance for error.

The results of the experiment that was conducted to evaluate this possibility were disappointing. Numbers were used as names for the dyads, and subjects were given trials in which they were to learn to name the dyads. The intention was to administer trials until a criterion of two consecutive errorless trials was attained. However, it soon became apparent that this criterion was unattainable, and the training of each subject was therefore discontinued when the experimenter was convinced that no further improvement would occur.

The touch tone code was probably difficult to learn because both of the tones in a dyad may vary from signal to signal. If only one tone varied from signal to signal, and the other tone served as a fixed reference against which the variable tone could be judged, a dyad code might be easier to learn. Accordingly, a second experiment was conducted in which subjects attempted to learn a code with 11 dyads as signals. The lower tone in each dyad was always the same, while the higher tone varied from signal to signal. The reference tone in each dyad was the bottom note in a major scale, while the 11 higher tones were the remaining 11 notes in that scale. As before, numbers were used as names for the dyads, and subjects were administered learning trials in which their objective was to learn the names of the dyads.

The results of this experiment, and the results of the earlier experiment in which names were learned

for touch tone dyads, are shown in Fig. 2. The two curves in this figure are learning curves for the two codes. The curves were determined by computing mean error scores for consecutive blocks of five trials, and by plotting these scores against trials. The graph indicates that although the dyads with fixed reference tones were learned more easily than the touch tone dyads, they were not learned well enough to warrant their use as code signals. If the tones in each dyad had been presented consecutively instead of simultaneously, there is little doubt that subjects would have found their identifications easier to learn. However, since the original objective was the practical objective of determining the suitability of a readily available device for displaying the values registered on digital displays, and since consecutive presentation of the tones in dyads would require the development of a new device, I have decided to discontinue this line of research.

The Use of Concurrent Abstract for Search and Retrieval in Tape-Recorded Texts

This project has been undertaken in collaboration with Maxwell A. Kerr, an electrical engineer who is the president of Ada-Max, an audio-visual engineering firm in Jackson, Michigan. Kerr contributed the concept of the concurrent abstract. He has made significant progress in developing a procedure for subjecting full text to a kind of scrutiny that permits the rapid abstraction of sequences of crucial words and phrases which, with only minor editing, form meaningful statements. When these statements are read in sequence, the result is an abstract which exactly parallels the full text, but which

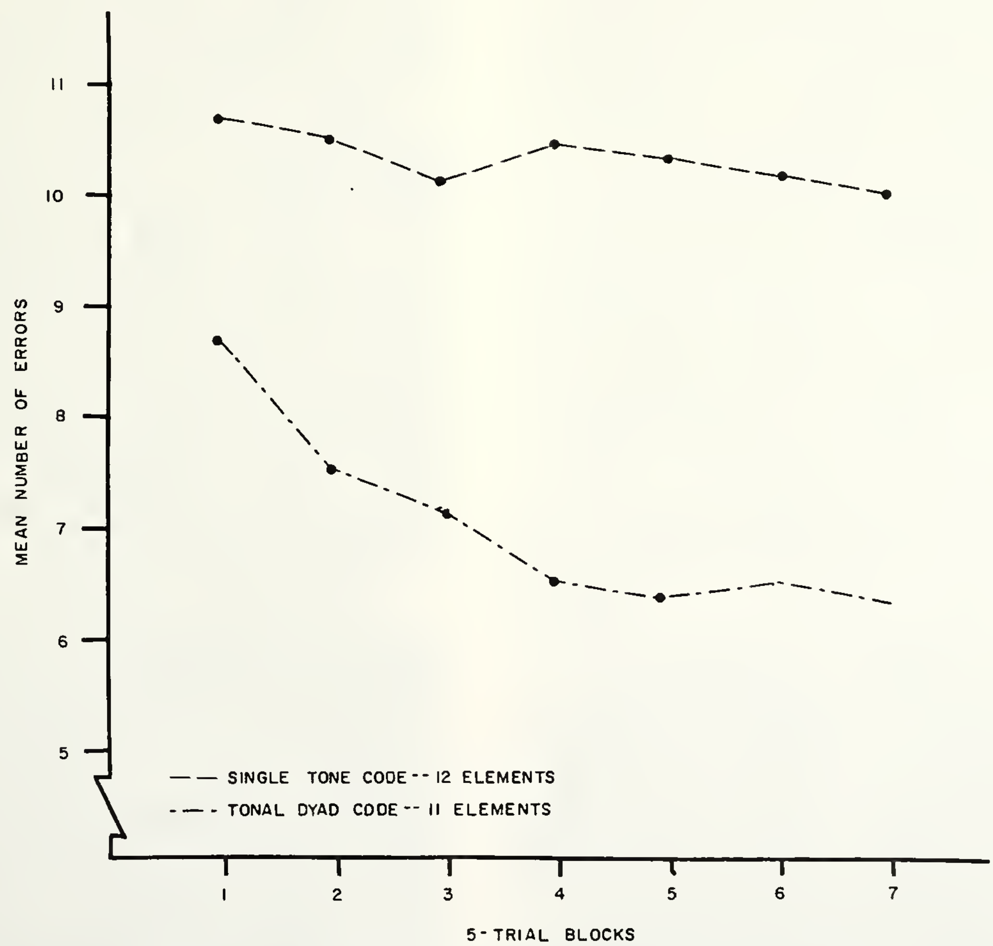


Figure 2. Ease of Learning Two Dyad Codes

is reduced to approximately one-eighth of the length of the full text. Although the procedure for creating the abstract is not yet fully developed, Kerr's results suggest that little training will be required for its mastery, and that people without background in the text that is to be processed can produce satisfactory abstracts of technical reports.

When a text has been abstracted in this manner, both the text and the abstract are typed, in adjacent columns, on rolls of chart paper. The transport mechanism of a chart recorder is used to wind the typed chart paper from its supply spool onto a take-up spool. The rate at which both the full text and the abstract are read orally is determined by adjusting the speed of the motor that drives the take-up spool. The oral reading of the text is recorded at a tape speed of 1-7/8 inches-per-second on one track of a tape. The oral reading of the abstract is recorded at 15 inches-per-second on another track on the same tape. If this tape is then reproduced at 1-7/8 inches-per-second, the signals obtained from the two tracks can be mixed and recorded on one track of a cassette. This cassette is reproduced on a cassette player that has been modified so that both the normal tape speed of 1-7/8 inches-per-second and a tape speed of 15 inches-per-second are available. When the cassette is played at the normal tape speed, the reading of the full text is heard against the background noise that results from reproducing the abstract recording at one-eighth of its recording speed. At this speed, the abstract recording is so low in frequency that it is unintelligible, and nearly inaudible because of the limited frequency response of the cassette player. When the cassette is reproduced at 15 inches-per-second, the abstract recording is heard against the background of high-pitched chatter that results from reproducing the full text recording at eight times its recording speed. At 15 inches-per-second, the full text recording is unintelligible, but it adds a considerable amount of noise to the signal in which the listener is interested and this noise may constitute unacceptable interference. This problem can be solved by copying the signals obtained from the full text track and the abstract track of the master tape on parallel tracks of a cassette. This cassette is reproduced on a cassette player that has been further modified by replacing the playback head with a stereo playback head, and by the provision of a switch for choosing between the two tracks scanned by this head. When the cassette is reproduced at the normal tape speed, the switch is set for the full text track, and the speech recorded on it is heard without interference. The first approach requires less modification of equipment and permits greater tape economy. The second approach results in a more satisfactory listening experience. The choice between the approaches will depend upon information acquired by consulting the experience of listeners.

Rapid scanning is an important ability of the visual reader that is not shared by the aural reader. This ability permits the visual reader to gain a general impression of the contents of a book and to locate sections of particular interest to him for more careful reading. When he is reviewing a book that he has already studied, the ability to scan rapidly permits him to spend his reviewing time efficiently. With cassettes prepared in the manner just described, scanning can become an ability of the aural reader, as well. Using a cassette with the proper format, and a cassette player with the necessary modifications, the aural reader might start by listening, at the fast tape speed, to the concurrent abstract, which would suffice to give him a good idea of the contents of the full text. When he encountered a section he wished to study more carefully, he would reduce his tape speed and listen to the full text.

The project just described is funded by a grant of $15,582.96, awarded to the University of Louisville by the Seeing Eye Foundation, Incorporated. The project is behind schedule because of difficulties encountered by Kerr in his efforts to provide the transport mechanism needed for handling chart paper, the tape recorder needed for making the full text and abstract recordings, and the modified cassette players on which cassettes are to be reproduced. However, the transport mechanism has now been delivered, and Kerr claims that the

remaining equipment will follow shortly. Donald Ferguson, a Research Assistant employed with project funds, has gained experience in the preparation of abstracts and the taped needed for completion of his project should be available before long. When these tapes are available, evaluation experiments will be conducted to determine the extent to which the availability of concurrent abstracts enables the aural reader to realize the advantages of rapid scanning.

The Talking Dictionary

The objective of this project is to record, on tape, the oral reading of a dictionary in a manner that will permit rapid search of the recorded format and efficient retrieval. The dictionary is presented on cassette. To prepare a cassette, two tape recordings are needed. One tape, referred to hereafter as the text tape, contains the full text of the dictionary. The other tape, referred to hereafter as the index tape, contains only the pronunciations of the words that are pronounced, spelled, and defined on the text tape. The index tape is recorded at 15 inches-per-second, which is an approximation of the fast-forward tape speed of the modified cassette players sold by the American Printing House for the Blind, when they are adjusted for a normal playback speed of 15/16 of an inch-per-second. In order to prepare a dictionary cassette, the text tape is reproduced at the speed at which it was recorded, and the index tape is reproduced at 15/16 of an inch-per-second. The signals from these tapes are mixed and recorded on one track of a cassette at 15/16 of an inch-per-second. To reproduce this cassette properly, two modifications of the conventional cassette recorder are required. Its motor speed must be continuously variable through a range that centers on a playback speed of 15/16 of an inch-per-second, and the playback head must not be retracted from the cassette when the recorder is placed in the fast-forward mode of operation. This second modification permits the tape to be scanned by the playback head when the cassette player is running at the fast-forward speed. The cassette players now supplied to blind and physically handicapped readers by the American Printing House for the Blind include the modifications required for the proper reproduction of dictionary cassettes. When the dictionary cassette is played on the modified recorder at 15/16 of an inch-per-second, the full text recording is reproduced properly. The index recording is reproduced at a speed that is so much slower than the speed at which it was recorded that it is nearly inaudible. Only an occasionally low-pitched rumble is heard, and it is unobtrusive. When the cassette player is placed in the fast-forward mode of operation, the index recording is intelligibly reproduced and displayed against the background of high-pitched chatter that results from reproducing the full text recording at the fast-forward tape speed. Since, at this speed, the full text recording is unintelligible, it adds only noise to the signal that is being processed by the listener and the interference it contributes is tolerable. As the listener scans at the fast-forward speed, he must make slight adjustments in motor speed in order to maintain the index recording at the proper pitch. Each word in the index recording is so located on the tape that its termination and the termination of the definition preceding the definition to which the index word refers occur at the same point on the tape. Each cassette contains a braille label and a large print label indicating the first and last word recorded on each track. By referring to these labels, the listener selects the cassette and the track containing the word in which he is interested, and plays the cassette at the fast-forward speed until he hears the word for which he is searching. He then changes to the slow-playback speed and listens to the spelling and definition of that word.

A somewhat different implementation of the talking dictionary has been made possible by an additional modification recently provided on the cassette recorders sold by the American Printing House for the Blind. These recorders are now available with stereo heads. A switch is provided that permits selection of either one of the two tracks scanned by the stereo head. This modification has been provided by the Printing House to permit the proper reproduction of cassettes with four tracks recorded

on them. We can take advantage of this modification by preparing dictionary cassettes with the text recording on one of the tracks scanned by the stereo head and the index recording on the other track. In addition to choosing the proper tape speed for the recording in which he is interested, the listener will have to use the selector switch to select the proper track, but by so doing, he will be able to hear the recording in which he is interested without interference from the other recording. The first approach has the advantage of requiring less modification of equipment, and it permits greater tape economy. The second approach results in a more satisfactory listening experience. The choice between these approaches will depend upon the preferences of experienced listeners.

The time required by a listener to consult this dictionary is considerably greater than the time required by the normal visual reader to consult a printed dictionary. However, if the alternative is a braille dictionary, the advantages of the talking dictionary are more apparent. The talking dictionary will require considerably less space and be significantly cheaper than a braille dictionary. Though a superior braille reader may consume less time in consulting a braille dictionary than he would in consulting the talking dictionary, the difference is not so marked as in the case of a visual reader, and it may disappear altogether in the case of a poor braille reader. Furthermore, most of the blind people who read by listening do not read braille at all, and for them, the talking dictionary may provide the only alternative to dependence on the assistance of a visual reader in consulting a dictionary.

This project was also described in last year's report, and that report included an account of the development of an improved device for automatic control of the tape players on which the text tape and the index tape are reproduced in order to prepare the final master tape from which cassettes are duplicated. By sensing control tones, this device starts and stops both tape players at the appropriate times, so that index words are correctly located on the final master tape with respect to the text segments to which they refer. This device is functioning satisfactorily, and an efficient procedure for producing final master tapes now appears to be at hand.

This project is being undertaken in collaboration with the American Printing House for the Blind. According to the understanding that was reached in planning this collaboration, the Perceptual Alternatives Laboratory is to develop the techniques and procedures for producing a talking dictionary. The Printing House will review these techniques and procedures, and if they seem suitable for large scale production, the Printing House will participate with the Perceptual Alternatives Laboratory in the conduct of field tests to determine the acceptability and utility of such a dictionary. If these field tests are affirmative, the Printing House will consider production of the dictionary. The techniques and procedures described in the preceding paragraphs, and in last year's report, have been developed to a point at which their evaluation by the Printing House is appropriate, and further progress on this project awaits the outcome of this evaluation.

In the meantime, an alternative procedure for the production of master tapes for the talking dictionary has been developed for consideration by the Printing House. Under this procedure, the tape players used to reproduce the text tape and the index tape are operated by a technician, instead of being controlled automatically. A technique is employed that permits very accurate timing of segments on the text tape and the index tape, and with this information, the technician can combine segments from the two tapes with a high degree of precision in constructing the master tape. Furthermore, he can monitor the process in which he is engaged, so that errors can be detected and corrected as they are made. The first method requires less of the time and effort of human operators. The second method permits more efficient detection and correction of errors, and because it permits greater precision in the combination of segments, there is less wasted time in the final master tape. The choice between these methods will depend upon their

comparative evaluation by the Printing House.

The Development of an Aural Reading Instrument

In one line of investigation carried on in the laboratory for several years, an effort has been made to identify, by analyzing the reading behavior of visual and aural readers, those operations that account for the relative efficiency of visual reading, and that are not ordinarily available to the aural reader. This analysis has suggested the functional requirements of a satisfactory aural reading instrument.

There is no piece of equipment on the commercial market that embodies all of the required functions. However, an office dictation machine manufactured in Switzerland, and distributed in this country by the Dictaphone Corporation can, with extensive modification, be made to incorporate enough of these functions to enable an evaluation of the improvement in reading effectiveness and efficiency that might be realized through the use of a functionally adequate reading instrument. Two of the dictation machines distributed by Dictaphone have been obtained. The Perceptual Alternatives Laboratory is now negotiating a contract with Bionic Instruments, Incorporated, a biomedical engineering firm in the Philadelphia area. Under the terms of this contract, Bionic Instruments will extensively modify the dictation machines so that they include enough of the functional requirements of an ideal aural reading instrument to qualify them as prototypes of such an instrument. These prototypes will record information on an oxide-coated plastic sheet instead of tape, because of the relative ease with which information recorded on that sheet can be accessed. A magnetic medium is preferred since its use will permit the construction of an instrument with the recording capability of a conventional tape recorder, and this capability should be given high priority in the design of an aural reading instrument. These prototypes will make provision for flexible review and preview, rapid search, and precise retrieval. They will be battery operated and portable.

When these prototypes are available, reading matter will be prepared for reproduction on them. A few aural readers will be given training in the use of these instruments, and their experience will be taken into account in designing more formal experiments to evaluate their contribution to the reading process, and in refinement of their functional capability.

The Development of an Aural Testing Instrument

Acquiring test information by listening to the recorded oral reading of a test form is an obvious alternative for those who, for whatever reason, cannot read print. However, if such a recording is reproduced on conventional equipment--record player, open reel tape player, or cassette player--the aural reader is handicapped. The person who acquires his test information by reading a printed test form can easily reread any test item if he is not sure of its meaning. He will typically read a few items once, many items twice, and a few items many times. Furthermore he can maximize the number of test items he is able to consider by passing over items that seem difficult to him on first reading, responding to the items he finds easy, and returning to difficult items for more thoughtful consideration. However, if the recorded oral reading of a test is reproduced on conventional equipment, the performance of these operations becomes so inefficient that the advantages gained by resorting to them are largely cancelled by the time that must be spent in performing them. Returning to a precise location on a conventionally recorded tape is a task that must be accomplished by a trial and error process of successive approximations. It consumes so much time and becomes so aggravating, particularly when it must be carried out under the time pressure associated with the taking of most tests, that the aural reader will usually elect to forego the advantages he might realize by retracing. If the test score earned by the aural reader is depressed because he has not had access to operations which contribute to successful test performance, and which are accomplished with ease by visual readers, his score will not be a valid

indicator of the ability the test purports to measure. As described in last year's report, arrangements were made for the design and construction, by Electronic Systems Development Corporation (known at that time as Biotronics, Incorporated), of a device to be used as an accessory to the cassette recorder sold by the American Printing House for the Blind. With the device connected to his cassette recorder, the aural test taker listens to a cassette on which test items have been recorded. At the end of each test item, a brief 60-cycle tone, recorded on the same track as the test item, is sensed by the device and the tape recorder is automatically switched off. The device incorporates a high-pass filter which protects it from the signal generated by the speech recorded on that track. If the operator wishes to proceed to the next item, he presses a momentary switch on the device, which starts the cassette recorder again. If he wishes to hear the item a second time, he must press the momentary switch on the device and then the rewind button on the recorder. He releases the rewind button when he hears a high-pitched tone. This tone is the 60-cycle tone that marks the boundaries between test items, but since the tape to which he is listening is being played at approximately 16 times the normal playback speed, the tone he hears has a frequency of approximately 1,000 Hz. Upon hearing the high-pitched tone, the operator stops the recorder, and the tape in the cassette is properly positioned for hearing the test item again. Of course, at the conclusion of the second hearing of the test item, the cassette recorder is automatically turned off as before, and the operator has the same options as before. He may repeat these operations as many times as he wishes. He may return to any desired test item by holding the rewind button down, and by counting high-pitched tones until he arrives at the tone marking the location of the item in which he is interested. If he loses count, he need only release his rewind button when he hears the next tone, and listen to the number of the test item indexed by that tone to find his place again. If he wishes to skip ahead, he can press the fast forward button on the cassette recorder and count high-pitched tones until he arrives at the location in which he is interested.

This device performs the functions for which it was designed. However, experience in using it revealed that it was inadequate in terms of human engineering. There were too many switches to operate, and the necessity of operating switches at two different locations--the cassette recorder and the remote device--in order to control a single process proved to be undesirable. In an effort to solve this problem, the components of the remote device were installed in the cassette recorder, itself. To do so, it was necessary to sacrifice the battery compartment. The power supply that permits operation of the cassette recorder from the 117-volt ac line proved to be marginally adequate in terms of filtering and current capacity, and the reliability of the control circuitry was not satisfactory. In addition, further consideration of this problem suggested that convenience of operation would be improved if the control circuitry were built into a cassette recorder that offers the review function. A recorder with this function has an additional control key. With the recorder in the playback mode of operation, pressing this key causes the cassette to be rewound. When the key is released, the recorder is returned directly to the playback mode. Since the recorder sold by the Printing House does not offer the review function, it was necessary to search for another recorder with this function that would be satisfactory for our purposes. A model manufactured by Sony has been identified, and one of these recorders has been purchased. The control circuitry will be installed in this recorder. In addition, its playback head will be replaced with a stereo playback head and a switch for choosing between the two tracks scanned by this head will be installed. Test items will be recorded on one track and control tones on the other track. Since the second track will contain only control tones, the circuitry that senses those tones will not have to include a high-pass filter, and the high-pitched tones that are reproduced when the recorder is in the fast forward or fast rewind mode will also operate the control circuitry. Consequently, when the review key is depressed, the cassette will be rewound only until a control tone is encountered. It will then be stopped, and the tape will be in the proper position for the rereading of a test item.

If these modifications are successful, several recorders will be purchased and modified in the same way. These recorders will be used in experiments designed to evaluate the difference that may be realized by the use of these machines for the administration of tests.

Testing the Articulation of the Votrax Speech Synthesizer

Vocal Interface, a division of the Federal Screw Works, has developed a speech synthesizer to which it has assigned the trade name "Votrax." The Votrax synthesizer is roughly the size of an attache case. It can be operated by parallel or serial code obtained from conventional code sources, such as computers, punched tape, etc., and it can be operated from a typewriter-like keyboard, on which phonemes are assigned to keys instead of letters. The quality of the speech synthesized by the Votrax synthesizer is surprisingly good, and since it can provide a voice for computers and many other devices that ordinarily display results visually, its potential for offering a perceptual alternative is considerable. Our first step in assessing this potential was to evaluate the Votrax synthesizer as an articulator. With the assistance of Max Bishop, a sales representative of Vocal Interface, the Votrax synthesizer was used to synthesize two 50-word lists of phonetically balanced words. Each word was appended to a common carrier phrase, also synthesized on the Votrax synthesizer. The output of the synthesizer was recorded on tape. Using the same common carrier phrase, the same two PB lists were recorded on tape by a professional announcer. Under my direction, Tony Ahl, a senior student at the University of Louisville, conducted an experiment in which two comparable groups of subjects were first given practice in the identification of PB words, and then asked to identify the natural words and the synthesized words in the test lists. One group heard the natural rendition of List A and then the synthesized rendition of List B. The other group first heard the natural rendition of List B and then the synthesized rendition of List A.

A subject's score was the number of words identified correctly. The four columns in Table 1 show the scores earned by subjects under the four experimental conditions. The mean score for each condition is shown at the foot of the column in which the scores earned under that condition are entered. Comparison of these means suggests that subjects found the natural speech more intelligible than the synthesized speech. It also appears that subjects found the synthesized words more intelligible when they were the first words to be identified than when they were identified after having first identified the natural words. The apparent differences among these means were examined by analysis of variance of test scores, and found to be significant.

We expected to find that natural words would be more intelligible than synthesized words, and in view of the fact that the intelligibility of single words can be degraded considerably without impairing the intelligibility of sentences formed with those words, it is our judgment that the intelligibility of the speech synthesized by the Votrax synthesizer is adequate for many of the applications in which we are interested. Furthermore, it must be remembered that our subjects in this experiment had no prior experience with the synthesized speech, and a lifetime of prior experience with natural speech. The order effect expressed in these results is puzzling, and its explanation will require further research.*

TABLE 1

A Comparison of the Articulation of a Human Speaker and the Votrax Speech Synthesizer

Group I		Group II	
Syn.	Hum.	Hum.	Syn.
50	94	98	25
60	95	95	42
63	97	98	43
70	91	83	43
77	98	98	46
80	97	97	53
$\bar{x}$=66.43	$\bar{x}$=95.43	$\bar{x}$=95.00	$\bar{x}$= 42.57

*An account of this experiment is given in the Senior Thesis written by Ms. Ahl.

The modest experiment just described is, of course, preliminary in character. Bishop and I are discussing the possibility of further research concerning the intelligibility of Votrax speech, and if suitable arrangements can be made, several experiments involving Votrax speech will be conducted in the Perceptual Alternatives Laboratory.

A Comparative Evaluation of the Signal Quality of Different Speech Compressors

In the past few years, rapid progress has been made in the development of the technology upon which the time compression and time expansion of recorded speech depends, and several electronic and electromechanical speech compressors are now commercially available. The Center for Rate-Controlled Recordings, a unit of the Perceptual Alternatives Laboratory, has, for many years, played a prominent role in the conduct of research concerning time-compressed and time-expanded speech. Because the Center has no commercial interests at stake, it has received requests from several manufacturers, as well as many of their prospective customers, for an objective evaluation of the signals produced by different speech compressors.

In last year's report, a plan was described for gathering the data needed for the comparative evaluation of speech compressors. Because of the imminent commercial availability of a couple of compressors still under development, we have postponed the study in the hope that we can include samples from these compressors in our evaluation. However, our plan is to compose sentences which adequately sample the phonemic spectrum, and record them on tape. These tapes will be compressed and expanded by several degrees, on each of the compressors under evaluation. The specimen prepared on each compressor will be submitted to the manufacturer of that compressor. If the manufacturer is not satisfied with its quality, the master tapes used in preparing the specimen will be made available to him, and he will be invited to prepare a specimen that fairly represents the performance of his compressor. When specimens have been collected, they will be presented to groups of listeners, who will be asked to reproduce, in writing, the sentences they hear. Each sentence will be scored for the number of words correctly reproduced, and an analysis of the errors represented in incorrectly reproduced words will be attempted. In another approach, the relative preferences of listeners for the signals of the speech compressors under evaluation will be determined. The listening experience upon which preferences are to be based will be provided by extended samples of fluent speech prepared on these compressors. With information about intelligibility, and information about the preference of listeners, it should be possible to make meaningful comparisons among the output signals of the commercially available speech compressors. The results of this study should be useful to manufacturers and to consumers.

The Role of Aural Reading in the Public School Program

Adequate functioning in the program of education offered by our public schools is predicated on the ability to read. In large measure, a child must obtain, from printed reading matter, the information he needs to succeed in the tasks set for him by his teachers. If he cannot read well, his ability to gather this information is impaired, and his performance is adversely affected. Public school educators are becoming increasingly aware of a large number of children in public schools who, in spite of persistent efforts at remediation, never learn to read effectively. They do not perform well in school, and it is tempting to conclude that their poor school performance and their poor reading ability are both the consequences of a superordinate learning disability. This may sometimes be the case, but experiments performed in this laboratory and elsewhere raise the possibility that some of the children who read ineffectively can listen effectively, and have the ability to succeed in school tasks, if they are not required to depend upon visual reading for information.

Last year, in collaboration with Marilyn Kreisle, the coordinator of the Learning Disabilities Program in the Louisville Public School System,

a proposal to study the efficacy of aural reading for learning disabled children was made to the Louisville Public School System. Because of a shortage of funds, the support requested by the proposal could not be provided, and our investigation of aural reading was temporarily suspended. However, we are now preparing another proposal in an effort to obtain funding for an investigation that we hope to initiate in time to get materials ready for use during the Fall Semester of 1975.

Through testing and observation, it has been determined that there are a significant number of children in the Louisville public schools, with better than average intelligence, who have seriously inadequate reading ability. They perform poorly in school, and it is apparent that they do so because they cannot acquire by reading the information they need for success in school tasks. We are proposing a study that will disclose the extent to which these children may benefit from the opportunity to read by listening. Parallel forms of a test of listening comprehension, one printed and one recorded on tape, will be administered to those children whose poor scholastic achievement appears to be a consequence of reading disability. Those children who, on the basis of test performance, can be described as poor visual readers but adequate aural readers, will be divided into an experimental and a control group. Members of the experimental group will be given the opportunity to do all of their studying by listening to recorded textbooks. The effectiveness of aural reading will be evaluated by comparing the experimental group with the control group on such indices as pretreatment and posttreatment scores on tests of scholastic achievement, school grades earned before and after service in the experiment, and the subjective appraisals of teachers.

Active-Versus-Passive Learning

It is generally true that learning proceeds more efficiently when the learning task is designed in such a way that behavior on the part of the learner is required to carry forward the learning process. Aural reading suffers by comparison with visual reading because its maintenance does not demand overt behavior from the aural reader. In order to read, the visual reader must continuously produce the behavior required for visual search of the printed page. If, because his attention wanders, or because he falls asleep, he fails to produce this behavior, the reading process comes to a halt. The aural reader is not required to engage in any specific overt behavior in order to maintain the reading process in which he is engaged. His attention may wander, or he may fall asleep, but the tape recorder or record player to which he is listening will continue to deliver its recorded message.

If this analysis is sound, it should be possible to increase the effectiveness of aural reading by finding a way to make continuation of the aural reading process contingent upon behavior produced by the aural reader. An experiment to evaluate this possibility is in progress, and its description follows.

A reading selection with a level of interest and difficulty suitable for use with college students has been chosen. A multiple-choice test covering the facts and implications of this selection has been developed. Its coefficient of reliability is 0.88. The selection has been recorded on track one of a stereo tape. Control tones have been recorded on track two of this tape at sentence boundaries. Two head sets are connected to channel one of the recorder on which this tape is played. One set is worn by the active listener, and one by the passive listener. Channel two is connected to an amplifier, the output of which is rectified and applied to the coil of a relay. The tape recorder used in the experiment is one on which provision has been made for the remote control of the start-stop function, and the remote control terminals are connected together through a pair of normally closed terminals on the relay. When a control tone is sensed, the relay closes, the normally closed terminals open, and the tape recorder stops. The relay is latched in this state so that the tape recorder remains stopped until the latch is broken by pressing a momentary switch. Since the control tones are recorded at

sentence boundaries, the tape recorder stops at the end of every sentence. The active listener must press the momentary switch in order to obtain each new sentence. His instructions suggest that he can operate the momentary switch immediately, or take advantage of the stopped tape in order to think about the sentence he has just heard before going on to the next one. The passive subject hears what the active subject hears, but he has no control over the delivery of sentences. The listening selection is also presented to a control group of subjects in the conventional manner. Upon conclusion of the listening selection, all subjects are tested for comprehension. When the experiment is finished, there will be three distributions of test scores, one for the group of active listeners, one for the group of passive listeners, and one for the control group. Only a few subjects have been run at this writing, and the data are too meager to suggest the outcome of the experiment.

A Dimensional Analysis of the Productions of Oral Readers

Aural readers express clear preferences with respect to oral readers. In some cases, the bases for these preferences are evident. However, in some cases, it is not easy to identify the factors that are evaluated by a listener in forming his preference. Even a superficial analysis suggests that several dimensions must be taken into account in evaluating the production of an oral reader, but it is not yet possible to specify these dimensions, or the way in which the dimensional values represented in the production of a given oral reader combine to form the product that is preferred by the listener.

In last year's report, an experiment was described in which subjects were asked to evaluate all of the possible pairings of 12 oral readers--four professional readers, four experienced amateur readers, and four inexperienced readers drawn from the student body at the University of Louisville, whose audition tapes were rejected by the panel of judges that selects volunteers for Recording for the Blind. The production of each reader was recorded, and samples lasting one minute were obtained from these recordings. By pairing each sample with every other sample, 66 pairs of samples were formed and rerecorded in a format that placed the two samples in each pairing on concurrent tape tracks. During playback, each of the samples in a pairing could be reproduced selectively by operation of a switch. The subject's task was to compare the samples in each pairing, and in each case, to express a preference for one of them.

As was expected, preliminary analysis of the data indicated that professional readers were, with one exception, preferred over experienced amateur readers, and that experienced amateur readers were, without exception, preferred over inexperienced readers. Since manipulation of oral reading ability produced the expected variation in listener preference, we seemed to have the kind of data that would be suitable for a dimensional analysis of reading ability. Accordingly, the data were punched on Holerith cards, and a computer was used to carry out an analysis, the objective of which was to disclose the multidimensional preference structure expressed by the subjects who served in the experiment. The analysis indicated that there is no single dimension which will account for the expressed preferences. However, the analysis that could be accomplished with the available computer program could sort preferences into only four dimensions, and there was no distribution of preferences among four dimensions that would account for the obtained results. A more complex analysis will apparently be required before these data can be explained satisfactorily, and no decision regarding the appropriate analysis has yet been made.

The Effect of Oral Reading Skill on the Comprehension of Time-Compressed Speech

Recorded oral readings of the eight selections in the comprehension subtest of the Nelson-Denny Reading Test were obtained from the 12 readers--four professional readers, four experienced amateur readers, and four inexperienced readers--who were employed in the experiment just

described. The recordings were used in an experiment conducted in collaboration with Dr. Normal Lass, a member of the faculty of the School of Medicine, Division of Otolaryngology, at West Virginia University. The recorded selections were presented at four different word rates--175, 225, 275, and 325 words-per-minute--to 480 subjects drawn from classes at West Virginia University. The 12 renditions of the reading selections and the four word rates at which they were presented combined factorially to produce 48 experimental treatments, and each experimental treatment was administered to 10 subjects. Their scores on tests covering the listening selections indicated that the renditions of skilled oral readers were more comprehensible than the renditions of unskilled oral readers, and at three of the four word rates, the data suggested that the renditions of male oral readers were more comprehensible than the renditions of female oral readers. However, this suggestion was not confirmed by an analysis of the variance of test scores. A full report of this experiment has been prepared and submitted for publication to an appropriate professional journal.

ACQUIRING INFORMATION BY TOUCH

Investigation of the ability to gather information by touch is a major activity of the laboratory. Included in this category are experiments concerning man's perceptual capacity with respect to dot patterns of the sort represented in the braille code, experiments to evaluate various schemes for expanding the braille code, experiments concerning factors that define the effectiveness of tactographic displays, and experiments concerning the haptic perception of form. Experiments in visual perception are also occasionally conducted in order to acquire data for comparative purposes.

Identification Thresholds for Moving Braille Characters

In an effort to understand the perceptual basis for braille reading, Nolan and Kederis have determined thresholds of identification for the 55 characters which stand for letters or small letter groups in the braille code. To do this, they employed a tachistotactometer. This is an instrument which controls the time of exposure for dot patterns. Patterns of dots rise above the display surface of the instrument to the height of a braille dot, remain in position for a preset time during which they press against the fingertip of the observer, and then recede below the display surface again. A psychophysical procedure is followed in determining the minimum time of exposure that is required for identification of the dot pattern, and the time thus determined is regarded as its threshold of identification. A possible difficulty with this method for determining thresholds is that it only minimally realizes an essential condition of cutaneous stimulation, a condition that is satisfactorily met when braille is read in the conventional manner. The excitation of cutaneous receptors requires movement of the tissue in which they are embedded. When a subject is stimulated by the dot patterns displayed on a tachistotactometer, tissue is moved by the dots used to form patterns as they rise above the display surface, and again as they recede below that surface, but not while they are stationary during the interval of exposure. On the other hand, when braille is read in the conventional manner, there is continuous movement of the cutaneous tissue in contact with the page as the fingertip passes over the dot patterns in the line of writing, and hence there is continuous excitation of cutaneous receptors. Thresholds of identification obtained under stimulation that more closely approximates the conditions of stimulation realized during the reading of braille may prove to be more useful in elaborating an account of the perceptual basis for braille reading than thresholds based upon the relatively static stimulation provided by the tachistotactometer.

In collaboration with John Kilpatrick, a graduate student who has conducted research in the laboratory, and with the cooperation of Fred Gissoni, Director of the Kentucky Industries and Rehabilitation Center for the Blind, who arranged the schedules of clients at the center so that they could volunteer as subjects, an

experiment was conducted in which braille readers were required to identify braille characters and words, embossed on a paper tape that passed beneath their fingertips. This tape is handled by a special tape transport, designed and constructed in the laboratory for this purpose. The tape is transferred from a supply reel, across a display surface, and onto a take-up reel. The subject under examination places his fingertip on the moving tape, and is stimulated by the dot patterns embossed on that tape as they pass beneath his fingertip. Tape speed is well regulated, and can be varied through a wide range.

Thresholds of identification were determined for braille characters, and for words composed with those characters. Thresholds were determined for words because Nolan and Kederis had found that, in many cases, the time needed for identification of a word exceeds the sum of the identification times for the characters of which that word is composed, and we wanted to know whether or not this finding would be replicated, using our method of determining thresholds. To determine thresholds for braille characters, the characters of interest are embossed on the paper page. Each character is separated from each other character by an amount of tape that will result in a satisfactory intercharacter interval when the tape is transported at the speeds to be employed in the experiment. The transport is initially adjusted for a tape speed that is too fast to permit identification of any of the characters under test. As the examination proceeds, tape speed is gradually reduced until all of the dot patterns have been identified. The tape speed at which a dot pattern is first identified is taken as an index of the threshold of identification for that character.

In the present case, thresholds of identification were first determined for 35 of the characters in the braille code. Then, the procedure was repeated, using 36 familiar words composed with these characters. Characters were presented to subjects at tape speeds that were calculated to produce exposure times of 0.02, 0.03, 0.04, . . . 0.14 of a second. Using these tape speeds for the presentation of words resulted in word rates of 500, 333, 250, 200, 167, 143, 125, 111, 100, 91, 83, 77, and 71 words-per-minute. Braille reading rates were also determined for the 10 subjects who served in the experiment.

The outcome of this experiment was rather complicated, and no effort will be made here to report a thorough presentation and analysis of the data. However, one of our findings is particularly deserving of comment. The finding of Nolan and Kederis that the time needed to identify words is frequently greater than the sum of the times needed to identify the letters with which that word is composed suggests that the reading of braille depends upon serial perception. The braille reader must identify each of the characters in a word, and then integrate these perceptions to achieve a word percept. In the present case, comparison of the times needed for the identification of words with the sums of the times needed for the identification of the characters with which those words are composed indicated that, in many instances, whole words were identified in significantly less time than the sums of the identification times for the characters in those words. This result may be inconsistent with the result reported by Nolan and Kederis, although further experimentation and analysis will be required to clarify the issue. Our result was observed in the performance of the faster braille readers in the experiment. It is reasonable to assume that faster braille readers find reading a more rewarding experience and that they have, as a consequence, done a good deal more reading. Their greater background of experience in reading may have enabled them to predict some of the letters in words with greater success than the slow readers. To the extent that successfully predicted letters do not have to be identified, the words in which they occur may be identified more quickly. However, there is another possible explanation for our result. With experience, some braille readers may learn a kind of perceptual "chunking" that permits them, in many cases, to treat whole words as unitary patterns. This perceptual ability should significantly reduce the time needed for the identification of chunked words, with rapid braille reading as a consequence. This is an important line of research

to pursue, because if by chunking some braille readers can read faster than others because they are able to reduce the number of patterns they must identify, and if a way can be found to teach this perceptual ability to others, it may be possible to bring about a general improvement in the rate at which braille is read.

The Reading Behavior of Exceptional Braille Readers

Much of the research concerning the perceptual basis for the reading of braille has had as its objective the elucidation of the processes underlying typical braille reading behavior. The process depicted by this research is one in which letter percepts, acquired serially, are integrated to form word percepts. Reliance on this process results in the slow reading rate (in the neighborhood of 100 words-per-minute for adult braille readers) that is typically observed. However, there are a few braille readers who read so rapidly (200 words-per-minute or faster) that their reading performance is not convincingly explained by a process involving the integration of serially perceived letters. In the course of collecting data for the experiment described under the preceding heading, two subjects with exceptionally fast reading rates were encountered. In the phase of that experiment in which whole words were presented on the moving tape, one of these subjects made accurate identifications at the fastest tape speed employed in the experiment. At the slower tape speeds, her identification times increased, and she began to make errors. She reported spontaneously that, at the slower tape speeds, word patterns began to disintegrate, and she was compelled to fall back on a strategy of identifying letters one at a time. The report of this subject, together with her reading performance, suggests that patterns consisting of whole words may frequently be the perceptual units of the process in which she engages as she reads.

Observation of this braille reader has revived an earlier interest of mine in an approach to the study of braille reading in which an effort is made to obtain a detailed and accurate description of the behavior of exceptionally fast braille readers, and to formulate and test hypotheses concerning the perceptual process implied by this behavior.

Last year's report contained the description of a plan for the investigation of rapid braille reading. This plan called for the identification of exceptionally fast braille readers for intensive examination. A variety of measures that might be related to braille reading ability, such as intelligence, cutaneous acuity, reaction time to cutaneous stimuli, age at which braille was learned, and so forth, would be obtained. In order to proceed with this investigation, it would be necessary to develop a means of closely observing the behavior of braille readers, and the design of an instrument intended to enable such observation was described. This instrument was constructed, but its functioning was marginal, and it could not be made to function satisfactorily with the adjustments permitted by its design.

With the assistance of Stewart Cooper, a photographer on the staff of the Department of Ophthalmology, the construction of a redesigned instrument is now nearly accomplished. As before, braille, written on a transparent sheet of plastic, is placed on a plate glass surface. An electric stopclock is also placed, face down, on this surface. A large, first surface mirror is positioned beneath the plate glass display surface at an angle of approximately 45°. A Super-8 motion picture camera is so positioned that it views the image reflected from the surface of the mirror, and the field of view is illuminated by two 300-watt photoflood lamps. To minimize problems that might be caused by glare, the lens of the camera is fitted with a polarizing filter.

With this instrument, the hands of a reader can be photographed as he reads. The result is a continuous film record of the reading behavior of the subject and of the time registered on the face of the timer. The hope is that a frame by frame analysis of this film will permit an accurate and detailed analysis of the different behaviors employed by the braille reader, and of the distribution of these behaviors in the time dimension. If

this approach is fruitful, it will lead to an understanding of the perceptual processes upon which rapid braille reading depends. With this understanding, it may be possible to formulate training procedures that will make these processes available to slow braille readers.

Increasing the Braille Reading Rate by Presenting Braille Characters at Controlled Rates

Last year's report included the description of a plan to explore the possibility of increasing the braille reading rate by giving subjects practice in reading connected prose, presented on moving tape at a speed that is gradually increased as practice proceeds. According to a current hypothesis, there is a kind of dynamic patterning involving whole words and phrases that is realized when the motion between the fingertips of the braille reader and the line of writing is maintained at a fast and constant rate. The ability to identify such patterns enables the exceptional braille reader to read braille at a rate that greatly exceeds the typical braille reading rate, and that compares favorably with the silent visual reading rate. If patterning of the sort required by this hypothesis is a reality, the ability to control the rate at which braille characters move across the fingertips employed for reading may make it possible to establish the conditions under which readers can learn to become aware of and to interpret this patterning.

The tape transport used in determining thresholds of identification for moving braille characters can be used in this study as well. Because of a shortage of research personnel, this study has not yet been initiated, but it will probably be conducted at the Kentucky Industries and Rehabilitation Center for the Blind, where clients of the center will be paid to serve as subjects in the experiment.

Identification Thresholds and Identification Times for the Characters in the Braille Code

In their investigation of the perception of braille, Nolan and Kederis determined the thresholds of identification for some of the characters in the braille code. To do this, they employed a tachistotactometer, an instrument that provides for temporal control of the intervals during which dot patterns are made available for tactual examination. The dot patterns to be examined are embossed on a sheet of paper mounted on a platform beneath the display surface. This paper is coated with plastic, and it will support dots of greater height than the dots which can be embossed on conventional braille paper. In order to present a pattern, the platform is elevated by solenoids, and the dots embossed on the sheet mounted on it are pressed through holes in the display surface, a thin membrane of tightly stretched metal with holes in it at locations corresponding to the dot positions in braille cells. The dots embossed on the sheet beneath the display surface protrude above that surface to the height of braille dots when the platform is elevated, and recede again when the platform is returned to its resting position. Up to 30 characters, or an entire line of braille writing, can be displayed at one time. The interval during which dot patterns are available for examination is controlled by an interval timer, connected in series with the power supply of the instrument.

Nolan and Kederis defined threshold as the minimum time of exposure needed for the identification of a character, and used a modified method of limits to estimate thresholds. Because of the time consumed in changing the sheets on which characters are embossed for presentation by the tachistotactometer, they found it expedient to emboss several characters on a sheet, and to determine thresholds for those characters before replacing it with a new sheet. Since a subject could quickly memorize the characters embossed on a single sheet, he could eliminate most of the characters in the code from his consideration, and thereby greatly reduce his uncertainty regarding the identity of any character presented to him for examination. To solve this problem, it was necessary to eliminate those series of stimulus administrations ordinarily employed in the method of limits in which the stimuli are initially above threshold, and to retain only those

series of stimulus administrations in which the stimuli are initially below threshold. Estimates of threshold obtained by this attenuated procedure are apt to be unduly influenced by errors of habituation.

Due to design limitations of the tachistotactometer, stimulus presentations could not be made brief enough to permit the administration of complete series of stimuli. The mass of the platform that had to be moved from one position to another and back again in order to present a stimulus, was so great that its movement could not be accomplished in the time allowed for very brief presentations, and for some of the characters in the braille code, it was not possible to make the time of exposure brief enough to preclude their identification. Consequently, thresholds for these characters could not be determined.

More precise estimates of thresholds of identification of the characters in the braille code may be useful in further analysis of the perceptual basis for reading of braille. Consequently, a study has been planned that seeks to eliminate the sources of error in the study reported by Nolan and Kederis. An instrument has been constructed that permits the presentation, one at a time, of all of the characters in the braille code. Dot patterns are formed by pins that rise through holes in the display surface. Each pin is driven by its own solenoid. The interval during which a character is available for examination is determined by an interval timer, connected in the common return of the power supply that energizes the solenoids. Since the mass of the pins that must be moved from one position to another and back again in order to present a dot pattern for an interval of controlled duration is smaller than the mass of the platform used for the same purpose on the tachistotactometer, and since the distance traveled by pins is much less than the distance traveled by that platform, much briefer stimulus presentations are possible with the new instrument, and stimulus values below threshold can easily be produced. Since any character in the braille code is immediately available for presentation on this instrument, the entire set of characters in the braille code can be brought under examination at one time.

The new instrument can also be used to determine the times needed for the identification of characters in the braille code. In this mode of operation, the experimenter selects a character for presentation by operating a keyboard. Pressing a key switch on the appropriate solenoids for the dot pattern controlled by that key, and their circuits are completed by a final switch closure, which operates a relay, connected in the common return of the power supply. When this relay closes, it also starts an electric stopclock. The relay latches when it closes, so that the character continues to be available for examination after its key is released. When the subject makes a vocal identification of the character under examination, he generates a microphone signal, which is amplified, rectified, and used to operate a second relay, connected in the latching circuit of the first relay. When the second relay closes, the first relay opens, the character under examination disappears, and the timer stops. The subject can then be scored for both time and accuracy of identification.

The apparatus just described will be used by Beth Challman, a member of the laboratory's staff, in the experiment she reports in her master's thesis. In this experiment, she will determine identification thresholds and identification times for the characters in the braille code. It will, of course, be useful to have more precise estimates of the thresholds of identification for the characters in the braille code, and the availability of identification thresholds and identification times will permit their comparative evaluation as predictors of such aspects of braille reading performance as the identification times for words, and the braille reading rate.

The Necessary Conditions of Stimulation for the Efficient Reading of Braille

It has already been pointed out in an earlier section of this report that movement of the tissue in which cutaneous receptors are embedded is

necessary for their excitation, and that more of this movement is produced when braille is read in the conventional manner than when braille characters are presented by pressing patterns of dots into a stationary fingertip. In order to explore this variable more thoroughly, an experiment is planned in which braille reading rates will be determined under several conditions of stimulation. In the first condition, braille characters will be displayed, one at a time, on the device used for determining identification thresholds and identification times, described in the preceding section. The device will be controlled by a punched tape reader. The rate at which this tape reader is stepped determines the rate at which characters are presented. In the next condition, the tape reader will be used to operate a device in which characters are formed by patterns of vibrating pins. These patterns will be presented one at a time to a stationary fingertip, but the increased movement of tissue produced by their vibration may result in an increased supply of receptor excitation from which the reader can acquire the information that specifies characters. The design and construction of this instrument has been undertaken by Electronic Systems Development Corporation, a biomedical engineering firm in the Louisville area, and it should be delivered to us before long. In the third condition, the paper tape transport described in an earlier section will be used to present a continuous line of braille characters that moves across the stationary fingertips of the reader. There should be almost as much movement under this condition of stimulation as under the normal condition of stimulation. Of course, the reader of a moving tape cannot preview or review as effectively as the reader of a braille page. In the final condition, the reading rate for braille presented in the conventional manner will be determined. The data obtained with this experiment may lead to a better understanding of the necessary conditions for effective cutaneous communication. Furthermore, the information provided by the experiment may be of use to designers in reaching decisions about the types of displays that are suitable for various applications.

Development of a Braille Page Embosser

Efforts are now underway at many locations in this country and elsewhere to take advantage of the rapid expansion of computer technology in implementing services for blind persons. These services could include the production of hard copy in braille at the user's terminal, but the braille page embossers currently available that would be suitable for use as terminal devices are so expensive that, in most cases, individual ownership is not feasible. To solve this problem, an effort has been undertaken in collaboration with Electronic Systems Development Corporation to develop a braille page embosser that will operate at teletype speeds and that can be manufactured at a low enough price (under $1,000) to make individual ownership feasible.

In last year's report, I indicated that a first generation prototype of the embossing mechanism had been constructed. Since then, with funds provided by the Grant Foundation, information gained by experience with this prototype has been used in constructing a second generation prototype. This mechanism appears to be functioning satisfactorily, and the carriage needed to transport it is now being designed. We hope that a working model of the embosser will be ready for test in a few months. Experience with this model should provide the information needed to complete the design of a model suitable for production. However, before this final phase can be carried out, it will be necessary to find additional funding.

THE PERCEPTUAL BASIS FOR MOBILITY

The perceptual basis for the skill that enables the blind pedestrian to reach his objective independently, safely, comfortably, and gracefully, is one of the laboratory's continuing research interests. Experiments have been conducted to evaluate the contributions of the physical characteristics of the cane employed by the blind pedestrian to

its effectiveness for gathering information. Techniques for the production of tangible maps have been studied because tangible maps constitute an important source for the information needed by the blind pedestrian for orientation and mobility. Although a program of research concerning orientation and mobility has been formulated for some time, active research in this area has been limited by the lack of funds. However, with the general laboratory support provided by the Grant Foundation, it has been possible to initiate programmatic research, and Clark Shingledecker, a graduate student employed as a Research Assistant in the laboratory, intends to make the investigation of orientation and mobility the basis for his doctoral dissertation.

A Rudimentary Theory of Mobility

A rudimentary theory of mobility has been formulated in an effort to account for the behavior of the blind pedestrian. This theory seeks to identify the operations upon which the blind pedestrian depends in gathering the information he needs to pursue a course of travel successfully. Although the theory has not yet received much experimental examination, in its current state of development, it provides guidelines for a systematic research effort.

The Development of an Improved Cane for Use by the Blind Pedestrian

Earlier research conducted in this laboratory has indicated the relevance of weight, length, rigidity, and form of tip as factors affecting the efficiency of the cane employed by the blind pedestrian to gather information. These factors have been taken into account in constructing a cane that appears to be more informative than canes currently in use. The aluminum tubing selected for construction of the new cane makes a shaft that is a little lighter and more rigid than the shafts of canes now in general use. It is equipped with a grip that fits comfortably in the hand and that permits the cane to be held securely so that it can be manipulated with greater precision. A new tip has been designed that permits the user of the cane to explore surface discontinuities more effectively. The tip is formed from nylon rod. The rod is bent to form an elbow, and it is this elbow which contacts the surface that is examined by the blind pedestrian as he walks. The portion of the rod extending beyond the elbow prevents the tip from becoming lodged in cracks or otherwise impeded when abrupt surface discontinuities are encountered.

Clark Shingledecker, a graduate research assistant employed in the laboratory, is currently conducting an evaluation of this cane. As a preliminary step, canes embodying the features just described have been given to experienced blind pedestrians in the Louisville community. When these critics have had the opportunity to use their canes for some time, they will be interviewed by Shingledecker, and their criticisms will be taken into account in refining the design of the cane.

With the assistance of David Stegner, the mobility instructor at the Kentucky School for the Blind; Wanda Biggs, a graduate student in the Orientation and Mobility Program at Western Michigan University; Dr. Richard Smith, a member of the Department of Psychology at the University of Louisville who has experience in the analysis of performance; and myself, Shingledecker has constructed a questionnaire designed to elicit information about the advantages and disadvantages of canes, and about how they might be improved to make them more serviceable. This questionnaire will be used by Shingledecker as an interview guide, when he interviews a large number of blind pedestrians exhibiting varying degrees of proficiency in the use of a cane.

The information obtained by these interviews, and the information obtained by consulting the experience of blind pedestrians who have used the preliminary model of the cane, will guide the construction of a new generation of canes. The redesigned canes will be subjected to more formal evaluation in field tests in which an effort will be made to develop measures of their effectiveness, and to compare them with conventional canes in terms of measured effectiveness. If the new canes survive these tests, arrangements will

be made for their production and distribution. Charles Cox, Director of Kentucky Industries for the Blind, has expressed an interest in evaluating the feasibility of their production in the workshop operated by his agency.

The Preservation of Cues to Distance and Direction in Tape Recordings Used for Mobility Training

In last year's report, there was a description of a method for recording environmental sounds that permits their reproduction with startling realism. The reproduced effects are so natural that it is difficult for the observer to believe that the sounds he hears are emanating from the earphones he is wearing. They appear to be definitely localized in the space surrounding him.

The vividness of this experience suggested a possible role for tape recordings of this sort in the courses of instruction in orientation and mobility that are provided for blind persons. Some progress was made in constructing the apparatus needed for such recordings, but the graduate research assistant who was working on the project left the university, and it has been necessary to suspend work on this project temporarily. However, the project will be resumed if a research assistant can be found who has the time and interest to pursue this line of research.

OTHER PERCEPTUAL ALTERNATIVES

Though the three areas of research on auditory perception, tactual and haptic perception, and the perception on which mobility depends have received major emphasis in the laboratory's research program, other perceptual alternatives have also received some attention. Accounts of these activities follow.

A Communication Device for Children with Profound Motor Disability

Last year's report included a description of a device that can be operated with the minimal movements remaining to persons with profound motor disability. This device enables the selective backlighting of 64 transparencies, arranged in eight columns and eight rows. Selection of the transparency to be backlighted is accomplished by the operation of two switches. Repeated operation of one switch causes the backlighting to be transferred from column to column across the display, while repeated operation of the other switch causes the backlighting to be transferred from row to row down the display. The switches are designed for operation by poorly controlled arm movements, because a girl at the Cerebral Palsy School in Louisville, who might benefit by this device, is capable of such movements. However, the switches can be designed for operation by any pair of independent movements, regardless of the parts of the body involved, or even by the myoelectric potentials that are generated when muscles are contracted.

A child unable to speak because of motor impairment could use the device for simple communication, by backlighting a transparency with some bearing on a current need. A picture of a glass of water might suggest to others that the operator was thirsty. A picture of a bed might signal the desire for sleep, and so forth.

In addition, the device might enable steps leading to the ability to read, by prompting an improved understanding of the relationship between words and the objects for which they stand. Training with the device might proceed in the following manner. The student first learns to select a variety of objects by operating the switches that control backlighting. Words naming those objects are then added to the transparencies used to depict the objects. After some experience with objects and their names, the student may discover that it is possible to achieve the same communicative outcome by selecting a transparency which displays only a name. He may

then learn to compose more elaborate messages by displaying sequences of words, and so on until he is engaging in reading behavior.

Initial experience with the device was quite encouraging. Children seemed to enjoy using it, perhaps because it enabled them to exercise some control over their environment--to make something happen. However, the attempt to use the device for instructional purposes revealed shortcomings. The prolonged switch closures produced by children with poor muscular control caused damage to the electronics. The inability to transfer backlighting from right to left as well as left to right, and up as well as down, proved to be a serious inconvenience. Also, since this device was only a laboratory model, it was much larger and heavier than necessary. However, our experience with the device has taught us how to improve it. The grant awarded by the Grant Foundation made specific provision for the support of further work on this project and Electronic Systems Development Corporation has nearly completed the construction of an improved prototype. If the new device appears to be satisfactory, several of the devices will be built and limited field testing will be initiated.

The Blind Child's Knowledge of the Anatomy and Functions of Sex

In the course of growing up, the child who sees has many opportunities to learn about sexual differences. He continually observes differences in body conformation, and unintended exposures give him occasional glimpses of normally concealed parts of the body. Furthermore, anatomical differences are explicitly shown in pictures to which the sighted child has easy access.

The blind child may have little opportunity to discover such differences. He can explore his own body, but he cannot see other bodies, and learning about them by touch is prohibited. Many blind children receive their education in residential schools, operated by the states in which they live. In these schools, there has been a tendency to avoid the problem that might result from sexual misconduct by carefully supervised segregation. As a result, the blind child who spends much of his life in a residential school missed the opportunities to learn about sexual differences that are ordinarily afforded by growing up in a family with brothers and sisters. Of course, the blind child becomes aware of the emphasis on sexuality in our culture, and this combination of curiosity and ignorance frequently leads to the formation of bizarre theories concerning sexual differences.

In recent years, there has been a growing conviction on the part of many educators that blind children, more than most, need adequate sex education. They argue that the blind child's lack of opportunity to acquire the experience that informs his sighted peer, and the misconceptions resulting from this lack of experience, predispose him to sexual maladjustment in adult life. On the strength of this argument, attempts have been made to provide sex education in many residential schools, although no satisfactory way has been found to show the blind child what the sighted child can see. Although a convincing case can be made for the provision of sex education for blind children, its validity depends, for the most part, on anecdotal evidence. There has been none of the systematic observation that would permit an accurate description of the state of ignorance of blind children concerning the anatomy and functions of sex, and no search for the relationship between that ignorance and the consequences that presumably ensue.

Two years ago, Thomas Uhde, a medical student at the University of Louisville, visited the laboratory to learn about its program of research and to explore the possibility of participating in a research project involving blind children. He had been working part-time at the Kentucky School for the Blind, and his experience included some counseling of adolescent boys. During his conversations with these boys, he had occasionally encountered some curious deficits in their sex knowledge. He discussed his findings with a member of the school faculty, who told him of the need for sex education in the

school, and of the school's interest in formulating a program of sex education. The curiosity aroused in Uhde by his experience at the school, together with the school's current interest in sex education, seemed to provide a climate that would be congenial to an investigation of the blind child's knowledge of the anatomy and functions of sex, and of the attitudes of parents and educators concerning sex education for blind children. Accordingly, an investigation was planned that calls for Uhde to interview blind adolescents, of both sexes, in order to discover what they know about sexual anatomy and the manner of its involvement in sexual behavior, and to obtain expressions of their attitudes concerning sexual behavior and its regulation. The plan of the investigation also calls for the preparation of questionnaires to be administered to the parents, and the house parents and teachers of blind children. These questionnaires are designed to elicit expressions of attitudes concerning sex education, and opinions concerning the method and content that would be appropriate in a course of sex education designed for blind children.

A grant of $750 was obtained from the Rauch Foundation to provide a summer salary for Uhde so that he could work on this project. At this writing, he has completed over half of the interviews. With assistance from members of the laboratory staff and members of the faculty at the Kentucky School for the Blind, he has constructed a questionnaire, and has sent over 2,000 copies to parents, schools, and other agencies. Approximately 500 of these questionnaires have been returned, to date. A preliminary report of the project on which Uhde is working was published in the May issue of *The New Outlook for the Blind*. Mr. Uhde plans to spend this summer completing the interviews and analyzing the questionnaires that have been returned. However, efforts to find a source for his summer salary have so far not been successful. Since he needs an income to meet living expenses, he may have to seek other employment, and in this case, it would be necessary to suspend work on the project.

Computer Services for the Blind

The ARTS system (ARTS is an acronym standing for Audio Response Time Sharing) was conceived by Dr. Kenneth Ingham, and he has brought the system to its present state of development. The ARTS system is a configuration of computing machinery that is programmed to provide a variety of services that should be useful to blind persons. These services are delivered by telephone, and since it is a time sharing system, 16 users can be accommodated at one time. The input to the system is provided by a typewriter-like keyboard, connected to the user's telephone. The output of the system is computer-compiled speech, heard over a loudspeaker, also connected to the user's telephone. Services planned for the system include dictionary consultation, composition of letters and other manuscripts, bookkeeping, filing, mathematical computation, transcription from print to braille, computer-aided instruction, computer programming, and so forth.

My report for the year before last included an account of the events I initiated that led to the establishment, by an action of the Kentucky State Legislature, of Computer Services for the Blind (CSB), a non-profit public corporation charged with implementation of the ARTS system and with the development of other computer-generated services for the blind citizens of Kentucky. The State provided $173,000 to meet CSB's costs during the first two years of its operation.

The transactions of CSB are supervised by a Board that includes the Director of the Division for the Blind, Bureau of Rehabilitation Services; the Superintendent of the Kentucky School for the Blind; the Director of Industries for the Blind; and six members appointed by the Governor of the State. I was one of those appointed by the Governor, and I am currently serving as Chairman of the Board. The Board appointed Glenn Smith as the first Director of CSB, and he served in that capacity until recently. The University of Louisville has made available to CSB, without charge, the space it needs for computing machinery for the administration of its business.

Initially, we believed that the development of the ARTS system was substantially complete. We expected to purchase a system which, after correcting the difficulties routinely encountered during the installation of a complex system, could be put immediately into service. However, as our attempt at implementation proceeded, it became apparent that considerable development of both hardware and software was still needed. As a result, we were unable to adhere to the schedule set forth in our proposal to the State of Kentucky.

By the beginning of the current fiscal year, the system was supposed to be delivering services and earning income to defray operating expenses. Instead, it is not yet operational. The principal hardware components of the system have been delivered and interconnected. However, the system, as it stands, does not have enough capacity to meet the anticipated needs for the storage of user files. The terminals provided with the system are only minimally adequate, and a source for better terminals has not yet been identified. The quality of the speech produced by the system is not quite satisfactory, and the system's vocabulary has not been selected with adequate care. Although some software has been created, a major developmental effort is still needed to provide the software that will be required for full implementation of the services that were expected when the system was purchased. The system was delivered without adequate documentation. CSB refused to accept the system without such documentation, and many months have been spent in acquiring it. A final acceptance procedure has been negotiated, and will be carried out shortly. If the vendor of the system can meet the tests specified by this procedure, responsibility for system maintenance will be transferred to CSB.

It is now clear to us that what we originally regarded as a service project will have to be regarded henceforth as a research and development project. The State of Kentucky funded our efforts in the expectation that services would be delivered. We have failed to do so, and the State of Kentucky is not interested in funding a research and development effort. As a consequence, our application for continuation of project support was rejected, and we will have to find another source of support in order to continue the project when current funds are expended. In spite of the difficulties we have encountered, we remain convinced that the ARTS system can provide the services originally claimed for it, but we now know that a developmental effort of considerable magnitude will be required before full implementation can be achieved. The time required for this effort will depend upon the level of support we are able to obtain, but with adequate funding, it can be accomplished within three years.

A first draft of a proposal has been written, and we are now searching for a funding agency that might be receptive to such a proposal. In the meantime, with remaining project funds, CSB plans to use the applications computer that is a part of the ARTS system for the transcription of print to braille and, if time and money permit, for the generation of tangible graphs and maps. In our judgment, both types of material are needed by the blind persons served by CSB, and with the addition of the appropriate accessories to the basic system already owned by CSB, we can easily develop the capability to produce these materials.

The Transcription of Print to Braille

The NOVA 800 computer that is a component of our ARTS system is adequate for the recording that is required for the transcription of print to braille. The print that is to be transcribed into braille is typed on a typewriter that creates a punched paper tape. This tape provides input to the computer. The output of the computer is used to operate an automatic braille page embosser. The system can be made more flexible if provision is made for storing the output of the computer so that it is not necessary to operate the page embosser on-line, and so that the output of the computer can be preserved for future use. In the system we have planned, teletypewriters will be used to punch the paper tapes that provide input. We have one teletypewriter, and another one is on order. We have also ordered the automatic braille page embosser manufactured

by Triformations. This machine embosses braille a line at a time, and it can emboss 120 lines-per-minute. We will be using cassettes to record the output of the computer, and these cassettes, when reproduced on a transport connected to the Triformations embosser, will control its operation.

In addition to the hardware components of the system, software will be needed to transcribe the input code to an output code that will cause the Triformations machine to emboss Grade 2 braille. CSB will contract with Glenn Smith, the former director of CSB, for the creation of the recoding program that is required.

The system we envision is one that will depend heavily upon volunteer services. A system manager will insure that the computing machinery is functioning properly, and will assist volunteers in the use of that machinery. However, volunteers will prepare input tapes, operate the braille page embosser, and bind brailled pages into volumes. Because we are using a minicomputer, our product will not be perfect. There will be occasional violations of the rules governing the use of contractions in the Grade 2 braille code. However, the occasional departures from perfect form will not have serious consequences for the reader. In fact, it is likely that many of them will be unnoticed by the average reader, who does not subject his copy to the scrutiny of a proof reader. Our primary objective is rapid response. We intend to satisfy the ongoing needs of students, and of blind persons engaged in professions and occupations. Under present management, there are well developed facilities for the volume production of braille, but there is inadequate provision for responding to individual needs. A blind person may request a group of volunteer transcribers to prepare a book for his use, but with the methods they currently employ, he will have to wait months for the delivery of that book. It is frequently the experience of the person who needs a book to meet educational or occupational requirements that, by the time the book can be delivered to him, the need for it has passed. If the system contemplated by CSB functions properly, it should be possible to bring about a very significant reduction in the time required to fill orders for transcribed braille reading matter.

The Production of Tactographic Displays

At present, there is no adequate source that can produce tactographic displays of high quality and that can respond to the needs of individual users. Orientation and mobility instructors are making increasing use of tangible maps, and it is likely that many blind pedestrians would use them regularly, if they could obtain them. Blind students could use raised line drawings of the graphs and figures in printed books to their advantage, but there are often no provisions for making these drawings available. The techniques currently used for the production of tangible displays make heavy demands on patience, skill, and time, and they are limited with respect to the variety of symbols that can be displayed with ease.

Dr. John Gill, a researcher at Warwick University, has developed a method for the construction of tactographic displays that appears to have many advantages over methods now in use, and with the addition of accessories to the computing machinery already owned by CSB, this system can be implemented and used to produce the tangible graphs and maps requested by the blind persons served by CSB.

Original composition of the tangible display is done at a computer terminal that includes a visual display unit, an analog control of the joy stick type, and a teletypewriter. The information required for the specification of symbols is stored in the computer. The supply of symbols includes symbols for points, such as dots, filled and unfilled circles, filled and unfilled triangles, stars, and so forth; symbols for lines, such as solid lines, dashed lines, broad and narrow lines, and so forth; and symbols for area consisting of a variety of surface textures. Teletype commands cause these symbols to be displayed on the visual display unit, where they can be positioned by operating the joy stick control. Dot patterns corresponding to the dot patterns in the braille code can also be added to

the display by teletype commands, and positioned by the joy stick control. When a satisfactory graphic display has been composed in this manner, the information that is needed to specify the composition of the display is encoded on punched paper tape. This tape is used to operate a numerically controlled engraving machine that engraves a negative of the graphic display on a sheet of plastic. From this negative, a rubber positive is made that serves as a master for use on a vacuum forming machine with which duplicates are made on plastic sheets. The advantages of this system include the relative ease with which graphis displays can be composed, the nearly inexhaustible supply of symbols for points, lines, and areas to which the composer has access, and the remarkably high quality of the end result. The use of an automatic engraver provides better control over the formation of symbols than has heretofore been possible, and the reduced variability among symbols of the same type permits a more reliable and more finely graded differentiation among symbols of different types.

If CSB implements this system, it will be necessary to purchase the visual display unit and the numerically controlled engraving machine. The teletype machine that is needed is already owned by CSB, and a vacuum forming machine is reliably accessible. Although we regard the services that can be provided by such a system as potentially quite valuable, our limited resources have made it necessary for us to establish priorities, and we have given first priority to the implementation of the system for transcribing print to braille. We will not make the decision to proceed with the implementation of the system just described until we have made enough progress in implementing the transcription system to be confident of our ability to complete its implementation.

SERVICES PROVIDED BY THE LABORATORY

The laboratory's principal business is the conduct of research. However, a continuing effort has also been made to provide useful services to educators and researchers in its field of interest. These services include the dissemination of information, the preparation of research materials, the development of equipment, and consultation with educators concerning the utilization of perceptual alternatives.

The Center for Rate-Controlled Recordings is a unit of the Perceptual Alternatives Laboratory. It was established to provide a source for time-compressed and expanded recorded speech of high quality, and at a moderate cost, for use in research and education, and to disseminate information concerning rate-controlled recorded speech. During the current year, the Center has continued to meet a steady demand for rate-controlled recorded speech and has continued its publication of the *CRCR Newsletter*. Many requests for information have been met through correspondence, telephone consultation, and consulting visits.

The most serious impediment to the application of recorded speech that has been compressed or expanded in time has been the lack of suitable equipment at a moderate price. However, efforts to develop moderately priced equipment have been underway at several locations. Several compressors have become commercially available in the last three years, and other compressors now under development will be available soon. Because of the prominent role played by the laboratory in the development of time-compressed and expanded speech, four manufacturers have donated compressors to the laboratory, and others have indicated an intention to do so shortly. The laboratory is now able to provide speech that has been compressed or expanded in time by a computer as well. It is becoming a museum of contemporary compression technology, and this should result in a further expansion of its role in the dissemination of information about time-compressed and expanded speech.

Audio-Tutorial Instruction

In audio-tutorial instruction, the objective is to make available to groups of students the advantages ordinarily associated with individual tutoring. This is accomplished by recording on tape the information

that would ordinarily be presented by a lecturer to a group of students, or by a tutor to an individual student. Careful attention is given to the organization of content and, in addition to the information that is given, the recording gives directions for learning activities in which the student is to engage. The recording is accompanied by a set of written learning objectives, which specify the student behavior that will constitute evidence of mastery. Mastery of each unit is required before the student is allowed to proceed to the next unit. Each student progresses through the course at his own rate, and every student who completes the course is assured of a passing grade.

Because of the laboratory's recording facilities, it is ideally suited for the preparation of audio-tutorial instructional materials. Over the past three years, these facilities have been used to prepare the materials required for the audio-tutorial presentation of an introductory course in Psychology at the University of Louisville.

The students in a typical class of blind school children show extraordinary diversity in their readiness for the course of instruction that is to be covered in the class. They show more than usual variability in intelligence, prerequisite learning, severity of handicapping condition, and so forth. As a result, no single instructional experience arranged by a teacher can be expected to be effective for more than a few class members, and the individualization of instruction becomes a necessity. Audio-tutorial instruction offers an attractive solution to this problem, particularly since blind school children have already had considerable experience in reading by listening.

Discussions have been held with members of the faculty at the Kentucky School for the Blind, in order to acquaint them with the possibilities offered by audio-tutorial instruction. An offer has been made to assist the school in the training of teachers and the preparation of audio-tutorial instructional materials. Will Evans, who has recently assumed the superintendency of the Kentucky School for the Blind, has expressed a strong interest in the use of audio-tutorial instruction, and I am currently working with him toward the preparation of an application for the support that will be needed to equip an audio-tutorial learning center, to train teachers in the production of audio-tutorial instructional materials, and to prepare the materials needed for a trial course.

Consultation

Since its inception, there has been a steadily growing awareness of the Perceptual Alternatives Laboratory and of its research program. As a consequence, the director of the laboratory is frequently invited to serve as a consultant to researchers and educators. During the current year, the director of the laboratory has continued to serve as a regular consultant to the Research Department of the American Foundation for the Blind; and to the Educational Research Department of the American Printing House for the Blind; and, as in the past, the director has continued to fill requests for consultation by State Departments of Education, school systems, and so forth. Consultation has covered the contributions of psychology, education and educational technology to the solution of problems engendered by visual and other perceptual impairments.

AUDITORY AND TACTUAL DISPLAYS FOR SENSORY AIDS FOR THE VISUALLY IMPAIRED

J. M. Gill*

The increasing use of digital displays, in particular the advent of inexpensive electronic calculators, has renewed interest in non-visual digital displays for the visually handicapped. However, relatively little information has been published on the various devices being developed. This survey is based on replies to a questionnaire circulated in August 1973; the main features of these displays are summarized here.

1.	Developer	American Foundation for the Blind 15 West 16th Street New York, New York 10011, U.S.A.
	Application	Output for electronic calculators, etc.
	State of development	A prototype has been produced but a new version with braille output is being developed.
	Description	Tactile display using binary coded decimal.
2.	Developer	L. Andersson Projekt AB Alea, Henriksbergsvagen 104, S-136 67 Handen, Sweden
	Application	Output for electronic calculators, etc.
	State of development	Two prototypes built.
	Description	Each dot consists of a small container filled with paraffin and covered with a flexible "window." A resistor is embedded in the paraffin so that an electric current through the resistor causes the paraffin to melt and expand; the flexible window forms an embossed dot. It takes about three seconds to change state.
	Price	Circa $50 for 6-digit display.

*Department of Engineering,
University of Warwick,
Coventry CV4 7AL, England.

TABLE 1

A Summary of the Main Features of the Displays

	Output Mode					Output			Application			State of Development		
Display number	Tactual	Audio	Parallel	Serial	Number of characters	Numerals only	Alphanumerics	Any shape	Output for electronic calculators, etc.	Reading machines	Active graphical displays	Prototype produces	Commercially available	Approximate cost in Pounds
1	+					+			+			+		
2	+		+		6	+			+			+		22
3		+		+		+			+					11
4		+		+		+			+			+		
5	+		+		25		+			+		+		300
6		+		+	12	+			+			+		250
7	+			+	10	+			+			+		
8	+		+		10	+			+			+		490
9	+		+		7	+			+			+		710
10	+			+			+			+		+		29
11		+						+			+	+		
12	+						+			+		+		
13	+			+	8	+			+			+		
14	+	+		+	4	+			+			+		140
15	+			+			+		+			+		
16		+		+				+		+			+	450
17	+		+		6		+		+	+		+		
18	+		+		3	+			+			+		
19		+						+			+	+		
20		+						+			+	+		
21	+		+		12	+			+			+		325
22	+			+		+			+			+		430
23	+		+				+		+	+		+		
24	+		+		8	+			+			+		110
25	+			+				+		+			+	1530
26	+		+		12	+			+				+	770
27	+			+		+			+					

3.	Developer	L. Andersson Projekt AB Alea, Henriksbergsvagen 104, S-136 67 Handen, Sweden.
	Application	Output for electronic calculators, etc.
	State of development	Proposal only.
	Description	An auditory output for presenting a half braille-digit at a time. A rotary switch selects the half of the digit which consists of two dots. The upper one is presented as a high note, the lower one as a low note and both as a medium note.
	Price	Circa $24.
4.	Developer	Privat-Doz. Dr. H. Bebie, Institut fur theoretische Physik der Universitat, Sidlerstr. 5, CH 3012 Bern, Switzerland and Prof. Dr. F. Fankhauser, Universitats-Augenklinik, Inselspital, CH 3010 Bern, Switzerland.
	Application	Output for electronic calculators, etc.
	State of development	Prototype built.
	Description	An auditory display which can produce the numbers 0 to 9 as spoken words which are stored optically.
5.	Developer	Clarke and Smith Research Ltd. Melbourne House, Melbourne Road, Wallington, Surrey, England.
	Application	Braille output device.
	State of development	General availability September 1975.
	Description	A 12, 25, or 72 character 6-dot braille display with bit serial input and solenoic activiated dots.
	Price	Circa £300 for 25-character display.

6.	Developer	Dr. A. J. Croft and D. T. Smith The Clarendon Laboratory, Department of Physics University of Oxford, Parks Road, Oxford OX1 3PU, England
	Application	Output for electronic calculators, etc.
	State of development	A dozen are being built for further evaluation.
	Description	Serial audio output with two tones--short tone is a single unit and a long tone is five units. It has been made on five printed circuit boards as an integral part of a calculator.
	Price	Circa £250.
7.	Developer	K. Cummins School of Engineering University of California 401 Verano Place Irvine, California, 92664, U.S.A.
	Application	Output for electronic calculators, etc.
	Description	The working prototype consists of two units--the tactile output device and the main calculator unit. The output device has a 10-digit capability but displays one digit at a time; a rotary switch selects the digit to be displayed. After the output is read for each digit, the pins are reset by hand.
8.	Developer	G. F. Dalrymple Sensory Aids, Evaluation, and Development Center Massachusetts Institute of Technology Cambridge, Massachusetts 02139, U.S.A.
	Application	Braille analogue of "Nixie" tube or 7-segment numeric display.
	State of development	Building 10 dual cell numeric only modules for further evaluation.
	Description	The braille display (four dots in the prototype) is composed of modules each containing two cells. These modules can be stacked to form a line of braille of any desired length. Each pin is connected by a lever to a solenoid; these levers are arranged in layers to prevent mechanical interference. The head can also contain a latch arrangement for holding the braille pattern without expending power in the main solenoids.
	Price	Display and drive electronics are estimated at \$100 per unit plus \$200 for each two digits, i.e., a 4-digit display is approximately \$500 or a 10-digit display \$1100.

9. Developer — The Electro Physics Company
9303 North Major Avenue
Morton Grove, Illinois 60053, U.S.A.

Application — Output for electronic calculators, etc.

State of development — In limited production.

Description — A binary coded decimal display with 7-digit capability. Each cell consists of 4 solenoid-operated pins.

Price — Circa $1600.

10. Developer — W. A. N. Ellis
Tudor Lodge Cottage
Fairmile Park Road,
Cobham,
Surrey, England.

Application — Braille display as an output for digitally stored information.

State of development — First prototype produced. General availability in 1975.

Description — Serial output to 6-dot braille cell operated by solenoids. The user can set the output rate.

Price — $65.

11. Developer. — Dr. R. M. Fish
1507 West Acre Road,
Joliet, Illinois 60435, U.S.A.

Application — A mobility aid when used in conjunction with a television camera. A non-visual equivalent to the cathode ray oscilloscope.

State of development — Prototype built.

Description — A binaural two-dimensional display has been developed. The frequency of the tone corresponds to the vertical position of the scan (200-7000 Hz). The relative intensities of the tones in each earphone are functions of the left-right position; interaural intensity differences as high as 40 dB are used.

12.	Developer	A. P. Grunwald Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439, U.S.A.
	Application	Braille display as the output module of the Argonne system.
	State of development	First production prototype.
	Description	Recirculating plastic belt with variable speed drive, means for writing and erasing, start-stop and speed control, timing pulse generator, speed 4-20 characters-per-second (up to 6 dots each). U.S. Patent #3,624,772.
	Price	$500 - $1500.
13.	Developer	R. J. Hitschmann Department of Engineering, University of Warwick, Coventry CV4 7AL, England
	Application	Output for electronic calculators, etc.
	State of development	Prototype built.
	Description	A serial 4-dot solenoid-operated braille display which can be connected to a commercially available electronic calculator.
14.	Developer	K. Isakson Karlavagen 90, S-115 22 Stockholm, Sweden.
	Application	Output for electronic calculators, etc.
	State of development	Prototype being evaluated.
	Description	The tactile display is read by moving the fingers over the array of braille cells; an audible signal indicates the correct figure in each array. The reading speed is about four figures per 10 seconds.
	Price	1500 Sw. Crs.

15.	Developer	R. E. B. Makinson and L. I. Paterson School of Mathematics and Physics, Macquarie University, North Ryde 2113, Australia.
	Application	Output for electronic calculators, etc.
	State of development	Prototypes built.
	Description	A serial 6-dot braille solenoid-operated display which can be interfaced for seven segments of BCD input. A thumb-wheel switch selects digits in turn. Supplemented by audible pip for a decimal point when the calculator display does not allot it a separate place.
	Price	Cost of materials A$ 15.
16.	Developer	Mauch Laboratories Inc. 3035 Dryden Road Dayton, Ohio 45439, U.S.A.
	Application	Reading aid.
	State of development	Commercially available.
	Description	The Stereotoner outputs 10 musical tones. The input is normally from a camera held over normal ink print, so the user has to recognize the characteristic set of tones for each letter.
	Price	$1020.
17.	Developer	J. Penksa Bialobrzeska 53, Warsaw, Poland
	Application	Output for electronic calculators, etc.
	Description	The Discon 201 is a 6-dot braille solenoid-operated display. The output is parallel to seven digits (polarity sign plus six digits); also includes six positions for the decimal point. The input is either BCD (1,2,4,8), BCD (1,2,2,4) or decimal. A 13-digit (sign plus 12 digits) display will soon be in production.
18.	Developer	Professor J. A. Phillips and Dr. P. N. Seligman Department of Electrical Engineering, Monash University, Clayton, Victoria, Australia.
	Application	Numeric display for use in a braille digital multimeter.
	State of development	Prototype built.
	Description	A 4-dot solenoid-driven braille display where the user presses a button to energize the 3-cell display.

19.	Developer	Professor J. A. Phillips and Dr. P. N. Seligman Department of Electrical Engineering, Monash University, Clayton, Victoria, Australia.
	Application	A non-visual equivalent to the cathode ray oscilloscope.
	State of development	Prototype built.
	Description	The instrument makes use of a multi-dimensional auditory display in which frequency, amplitude and timbre are all utilized. The instrument, which incorporates a signal-sampling time-scaling device, can be connected to an essentially conventional cathode ray oscilloscope.

20.	Developer	T. Robinson University of Manchester Institute of Science and Technology, Manchester, England.
	Application	A non-visual equivalent to the cathode ray oscilloscope.
	State of development	Prototype built.
	Description	A voltage controlled oscillator gives an audio display in which the frequency depends on the y deflection.

21.	Developer	Dipl. -Ing. K. -P Schonherr Arbeitsgemeinschaft fur Rehabilitationstechnik an der Universitat Stuttgart e.V., D-7000 Stuttgart, Schloss Solitude, Haus 3, West Germany.
	Application	Output for electronic calculators, etc.
	State of development	Prototype built.
	Description	The prototype consists of two units--the tactile output device and the commercial pocket calculator. The output device has a 12-digit braille display (5 dots from a 6-dot braille cell).
	Price	DM 2000 total.

22.	Developer	Science for the Blind Products 221 Rock Hill Road, Bala-Cynwyd, Pennsylvania 19004, U.S.A.
	Application	Output for electronic calculators, etc.
	State of development	Production models have not yet been built.
	Description	The CALCU-TAC is a braille printout system for use with electronic calculators. When printout is required a "print" button is pressed. The braille printer will print all the numbers in the display in proper sequence, including decimal. The braille printer will print out on narrow tape.
	Price	Circa \$700 - \$1000 but possibly \$500 when in full production.
23.	Developer	N. B. Sutherland The Mitre Corporation, Bedford, Massachusetts 01730, U.S.A.
	Application	Braille output device.
	State of development	Prototype built.
	Description	The six pins of a braille cell are operated pneumatically and locked in position by a solenoid.
24.	Developer	Tactile Display Systems, Inc. 911 South Owen Street, Mount Prospect, Illinois 60056, U.S.A.
	Application	Output for electronic calculators, etc.
	State of development	Working prototype.
	Description	An electronic calculator with a 9-digit braille solenoid-operated display. The braille is displayed when the momentary push button switch is pressed. This can be utilized at any point during calculation. The decimal point is presented by blanking one of the nine digits giving an eight digit display capability.
	Price	Circa \$250 each for 1000 machines.

25.	Developer	Telesensory Systems, Inc. 1889 Page Mill Road, Palo Alto, California 94304, U.S.A.
	Application	Reading aid for print and many electronic calculators and cathode ray tubes.
	State of development	Commercially available.
	Description	The Optacon has a camera which displays an enlarged tactual version of ink print text on a 24 x 6 array of vibrating reeds. The display consists of highly efficient piezoelectric bimorph stimulators (250 Hz). Tactile stimulator format: rods spaced 45 mils vertically, 90 mils horizontally, with an overall area 1.1 x 0.55 inches.
	Price	$3450.
26.	Developer	Telub AB Fack, S-351 01 Vaxjo, Sweden.
	Application	Output for electronic calculators, etc.
	State of development	General availability in Spring 1974.
	Description	A 4-dot braille display for connection to a binary coded decimal output. A 12-digit version is intended for use with calculators; presentation includes sign and decimal point (fixed or floating). A 5-digit version is intended for use with digital voltmeters, counters and similar equipment.
	Price	The 12-digit display, including a Facit 1118 calculator, will cost approximately Skr. 8000.
27.	Developer	Brother G. Kane Physics Department, Manhattan College, Bronx, New York 10471, U.S.A.
	Application	Output for electronic calculators, etc.
	State of development	Feasibility study completed. Patent pending.
	Description	Braille output is detected by electrocutaneous stimulation using concentric electrodes activated by constant current bipolar pulses.

NON-VISUAL COMPUTER PERIPHERALS

J. M. Gill*

Non-visual computer peripherals have been developed for:

1. Braille production,
2. Information retrieval systems,
3. Outputs for reading machines,
4. Blind programmers.

A survey of devices in production, or under development, based on replies to a questionnaire circulated in May 1974. The main features of these devices are summarized in Table 1.

A selected bibliography on the use of computers by the visually impaired, but excluding papers on speech synthesis and the employment and training of blind programmers, is at the end of the report.

1.	Developer	American Systems, Inc. 123 Water Street Watertown, Massachusetts, 02172, U.S.A.
	Status	Commercially available as part of the ARTS system.
	Description	Compiled speech output delivered over telephone lines. ASI speech and teleprocessing system Nucleus 3000 V/L with central processor and 8192 x 16 bit core memory, ASI 16-line multiplexer with receiver data sets or modems and speech storage disc capable of containing up to 500 seconds of speech definable as more than 2000 English spoken words.
	Price	$66,700
	Information	Dr. K. R. Ingham, June 1974.

*Department of Engineering,
University of Warwick, Coventry,
CV4 7AL, England.

TABLE 1

Summary of the Main Features of the Devices

	Device	Speech-like	Tactual Soft Copy	Braille Paper Tape	Braille Page	Speed Chars./Sec.
1	ARTS	+				
2	Anderson				+	3.3
3	Boiten			+		
4	Boldt					
5	Boldt					
6	Brown			+		10
7	Charlesworth		+			
8	Gee				+	10
9	Grunwald		+			
10	Haskins	+				
11	Heginbotham				+	60
12	de Jong				+	200
13	Kruger		+			
14	Loeber				+	16
15	Longini	+				
16	MIT				+	16
17	Myers				+	
18	PAL				+	10
19	Rahimi	+				
20	Rubenstein				+	10
21	Schonherr		+			30
22	Spanjersberg				+	7
23	Tagg				+	8
24	Telesensory		+			
25	Thiel			+		12
26	TNO				+	4
27	Trask				+	8192
28	BD-3			+		15
29	LED-120				+	15
30	LED				+	120
31	Wienberger			+		
32	Zawistowski			+		12
33	IBM				+	250

2. Developers — G. B. Anderson and D. W. Rogers
Lawrence Radiation Laboratory
University of California
Livermore, California, U.S.A.

Status — Unknown

Description — New print head for Model 33 teletype. Speed one third that of the normal teletype.

Information — Research Bulletin, No. 22, Dec. 1970, pp. 111-117.

3. Developer — Prof. Ir. R. G. Boiten
Laboratorium voor Werktuigkundige
meet-en Regeltechniek Technishe Hogeschool
Stevinweg 1
Delft, The Netherlands.

Status — Experimental prototype.

Description — Braille printer, powered by electric motor, which prints on Kraft paper tape moving from right to left.

Information — Research Bulletin, No. 26, June 1973, p. 219.

4. Developer — Professor Dr. Werner Boldt,
Pedagogische Hochschule Ruhr
Dept. of Educ. and Rehab. of the Visually Handicapped
46 Dortmund
Kreuzstr. 155
West Germany.

Status — Commercially available.

Description — Electronically-controlled system for programmed learning of the blind. Audio and braille output freely combined. Braille and multiple choice input according to the character of the program. Braille input electrically evaluated as well as multiple choice input. Branched programs--branching controlled by the input modes. All information (audio, braille, memory, coding) stored on magnetic tape (cassette type). During stop periods use as electronic braille-writer, with program cassette or additional material useful for most school subjects.

Price — Circa $2,800.

Information — Prof. Dr. W. Boldt, May 1974.

5. Developer — Professor Dr. Werner Boldt
Pedagogische Hochschule Ruhr
Dept. for Educ. and Rehab. of the Visually Handicapped
46 Dortmund
Kreuzstr. 155
West Germany.

Status — Prototype development.

Description — "Braillex" enables the blind user to reach prestored information with relatively short access. Information (verbal or braille) is stored and coded on magnetic tape cassettes. Verbal and braille output (for control) is possible. The information wanted is "called" by braille input and discriminated electronically. Examples: information from dictionaries, storing and use of private archives (telephone numbers, scientific notes, etc.), recalling of special parts in literature (pages, chapters, code words).

Information — Prof. Dr. W. Boldt, May 1974.

6. Developers — V. Brown and E. Stuckey
Teletype Corporation
Little Rock, Arkansas, U.S.A.

in collaboration with:

E. Knoch
Arkansas Enterprises for the Blind, Inc.
2811 Fair Park Boulevard
Little Rock, Arkansas 72204, U.S.A.

Status — One prototype built.

Description — The device, which produces braille at 100 words-per-minute, is in parallel with a standard model 32 or 33 printer so there is keyboard input, print output and braille output simultaneously. The unit consists of a modified punch which punches two rows of three dots each or two rows of four dots each, depending on the need, instead of the 8-bit ASCII.

Price — The original price of duplicating this unit in quantity was estimated to be $1600. However, with the modern LSI circuits available, it is felt that this device could be duplicated for under $600.

Information — E. Knoch, June, 1974.

7.	Developer	D. V. Charlesworth Clarke and Smith Industries, Ltd. Melbourne House Wellington, Surrey, England.
	Status	Prototype built, general availability mid 1976.
	Description	12, 24, or 72 character 6-point braille display with solenoid operated dots module and computer terminal/information retrieval unit. Fresh lines of information are obtained by pressing button at end of line.
	Price	£300 - £1600 depending on application.
	Information	D. V. Charlesworth, May 1974.
8.	Developer	Dr. M. J. Gee Scientific Systems Group Office of Computing Activities University of Dayton Dayton, Ohio, 45409, U.S.A.
	Status	Prototype
	Description	A paper embosser which employs an ASR 33 terminal, and produces a configuration of seven dots arranged in an expanded braille cell, with the addition of a seventh position below position six.
	Information	Association for Computing Machinery Newsletter for Blind Computer Programmers 4th Issue, Vol. 2, No. 1, page 5.
9.	Developer	Dr. A. P. Grunwald Engineering and Technology Division Argonne National Laboratory 9700 South Cass Avenue Argonne, Illinois 60439, U.S.A.
	Status	Production prototype.
	Description	Device converts symbols recorded on magnetic tape to raised braille dots on a plastic belt. The belt moves conveyor-like at an adjustable speed; the dots are "erased" by depressing them and new ones raised.
	Information	Research Bulletin, No. 23, June 1971, page 106.

10. Developer — Haskins Laboratories, Inc.
270 Crown Street
New Haven, Connecticut 06510, U.S.A.

Status — Prototype.

Description — Full text-to-speech processing system is now working in the laboratories. The synthetic speech is not entirely natural although intelligible. Sufficient progress has been made to justify the construction of a pilot reading service center which would have a combined research and service function.

Price — $350,000

Information — P. W. Nye, June 1974.

11. Developers — Professor W. B. Heginbothan,
D. W. Gatehouse, and D. G. Hassel
University of Nottingham
University Park
Nottingham, NG7 2RD, England.

Status — Design study.

Description — A terminal to produce a 36-character-wide line of braille print at a speed of 60 characters-per-second operating on a line printer principle. Also, meant to be adaptable to desk calculating machine. The machine sets up the braille terminals by operating from a bank of seven electromagnetic devices.

Price — Estimated £1000.

Information — Prof. W. B. Heginbothan, May 1974.

12. Developers — Professor D. de Jong and Ir. A. N. Westland
Technological University Delft
Leeghwaterstraat 3
Delft, The Netherlands

Status — First prototype ready in July 1974

Description — Braille lineprinter operating with papertape as input or on-line with a computer. Working on normal braille paper (180 gsm), printing five lines-per-second, each one consisting of maximum 40 braille cells.

Information — Ir. A. N. Westland, May 1974.

13. Developer — F. Kruger
National Center for Deaf Blind Youths and Adults
New Hyde Park, New York 11040, U.S.A.

Status — Prototype available.

Description — A single-cell softcopy braille display which can be connected to a computer via an acoustic coupler.

Information — Electronics, 7th February 1974, page 46.

14. Developer — N. Loeber
IBM Corporation
P.O. Box 66
Los Gatos, California 95030, U.S.A.

Status — Experimental unit.

Description — Page braille embosser, based on standard IBM terminal. The unit embosses from the rear, with the data appearing on the front side of the paper. A metal die is used to mate with the selected pins to provide positive control in forming the raised dots.

Information — American Federation of Information Processing Societies, Vol. 39, 1971, pp. 79-87 and N. Loeber, June 1974.

15. Developer — Professor R. L. Longini
Medical Systems Engineering Laboratory
Carnegie-Mellon University
Pittsburgh, Pennsylvania 15213, U.S.A.

Status — Fourth generation device built.

Description — An alphanumeric audio output where the sounds are voice-like enough so that 100 percent phonetic output can be learned as a dialect. Forty hours of training (high IQ) permits 150 words-per-minute of English to be understood.

Price — Circa $300 if built in quantity.

Information — Professor R. L. Longini, June 1974.

16. Developer — Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, Massachusetts 02139, U.S.A.

Status — Commercially available but supply limited.

Description — The Brailleemboss is an automatic braille printer which can operate at speeds up to 16 characters/second.

Information — Research Bulletin, No. 24, March 1972, page 161.

17.	Developer	F. H. Myers Bell Telephone Laboratories, Inc. 6200 East Broad Street Columbus, Ohio 43213, U.S.A.
	Status	Laboratory prototype.
	Description	A braillewriter was modified for electronic control. Seven solenoids and seven contacts were added.
	Information	Research Bulletin, No. 24, March 1972, page 164.
18.	Developer	Perceptual Alternatives Laboratory 358 Life Sciences Building University of Louisville Louisville, Kentucky 40208, U.S.A. in collaboration with Electronic Systems Development Corporation.
	Status	Second prototype built.
	Description	Braille page embosser that will operate at teletype speeds.
	Price	Under $1000.
	Information	Annual report of Perceptual Alternatives Laboratory, July 1974.
19.	Developers	Professors M. A. Rahimi and J. B. Eulenberg Department of Computer Science Michigan State University East Lansing, Michigan 48824, U.S.A.
	Status	Limited production.
	Description	The system uses the speech synthesis hardware/software package implemented on Michigan State University's main computers. The buffered output is normally operated at 300 Baud. The phonetic images of words and sentences are built up by concatenation of 8-bit symbols representing the phones of English in the buffer memory. The 8-bit code consists of six bits representing the phone and two bits representing one of four levels of intonation.
	Price	$4000 - $5000 per unit.
	Information	Professor M. A. Rahami, July 1974.

20.	Developer	R. Rubenstein University of California Irvine, California 92664, U.S.A.
	Status	One off-working model.
	Description	A teletype terminal was adapted to produce braille print-out.
	Information	Research Bulletin, No. 24, March 1972, page 161.
21.	Developer	Dipl. -Ing. K.-P. Schonherr Arbeitsgemeinschaft fur Rehabilitationstechnik an der Universitat Stuttgart e.V. D-7000 Stuttgart 1 Schlob Solitude, Haus 3 Germany.
	Status	Prototype.
	Description	The device is an electromechanical modular display, the module being a 6-dot braille cell such that braille lines of any desired length can be made. Writing speed is 30 characters-per-second.
	Information	Dipl.-Ing. K.-P. Schonherr, June 1974.
22.	Developer	A. A. Spanjersberg Dr. Neher Laboratory St. Paulusstraat 4 Leidschendam, The Netherlands.
	Status	Six printers have been built.
	Description	The seven bits of a braille code have to be presented in parallel to the input. The braille characters are embossed on the paper which is transported in the printing mechanism by pin feed. The speed is about seven braille characters-per-second.
	Price	D.Fls. 15,000.
	Information	A. A. Spanjersberg, May 1974.

23.	Developer	Dr. W. Tagg Hatfield Polytechnic Hatfield, Herts, England. In conjunction with the Royal National Institute for the Blind and Business Data Products, Ltd.
	Status	Prototype built and in daily use.
	Description	For Output - IBM Model D braille typewriter plus sighted typewriter. For input - specially designed keyboard. These three components are linked electronically to each other and to a standard Datel data transmission unit.
	Information	M. Jenkins, Hatfield Polytechnic, May 1974.
24.	Developer	Telesensory Systems, Inc. 1889 Page Mill Road Palo Alto, California 94304, U.S.A.
	Status	Prototype being evaluated
	Description	Hewlett-Packard (Santa Clara) have developed an ASCII to Optacon interface bypassing the Optacon's camera to feed the signals directly into the circuitry.
	Information	Measure (Hewlett-Packard), May 1974.
25.	Developer	Ing-Buro Thiel 6105 Ober-Ramstadt Grafengasse 2, West Germany.
	Status	Commercially available from stock.
	Description	Braille tape input-output attachment to enable blind person to operate telex-teleprinter machines. Output speed is 12 braille characters-per-second.
	Information	International Catalog of Aids and Appliances for Blind and Visually Impaired Persons, 1973.
26.	Developer	T.N.O. Delft, The Netherlands.
	Status	One off-working model.
	Description	Input is from eight hole punched paper tape which is fed to a modified Perkins brailler and automatic cutting apparatus. A code-translator has a maximum capacity of one braille plate embossing and six braille printing machines. The speed of production is four characters-per-second.
	Information	Research Bulletin, No. 25, January 1973, page 266.

27. Developer — Trask Datasystem AB
Stockholmsu, 34
182 74 Stocksund, Sweden.

Status — Prototype being built.

Description — The Zoltan Braille Embosser is a fully automatic system which can provide single copy documents at the rate of 10 seconds-per-sheet embossed on both sides (interpoint). A second sheet with the same text takes 1 second and all additional copies 1/4 second each. The quality will be equivalent to that obtained from rotary press using zinc plates. All the functions of the machine are controlled by an electronic digital controller. Text input is made with paper or magnetic tape or alternate as desired. For this reason the acquisition and storage costs of a text library are minimal.

The machine contains two embosser drums which print both sides of a sheet simultaneously. Each drum contains 6720 movable pins. The input text determines the position of each pin, which in turn embosses the paper to provide the corresponding braille text.

Price — Circa Skr. 200,000.

Information — Trask Datasystem AB, May 1974.

28. Developer — Triformation Systems, Inc.
P.O. Box 127
Wall Street Station
New York, New York 10005, U.S.A.

Status — Commercially available, delivery 90 to 120 days.

Description — The BD-3 is a portable unit which produces braille on paper tape, when used in conjunction with a keyboard, digital equipment, a computer, almost anything that uses coded information. Weight - 15 pounds. Speed - up to 15 cps. Operating modes - EIA interface, TTY interface (other interfaces optional). Input code - ASCII, EBCD, BCD, Correspondence, Baudot, any code with eleven bits per character or less.

Price — $1850

Information — Triformation Systems, Inc., June 1974.

29. Developer — Triformation Systems, Inc.
P.O. Box 127
Wall Street Station
New York, New York 10005, U.S.A.

Status — Under development.

Description — The LED-1 is a stand-alone braille device which produces braille from a keyboard, from a computer, from almost any coded information on a page of paper. Speed up to 15 cps. Operating modes - EIA interface, TTY interface (other interfaces optional). Input code - ASCII, EBCD, BCD, Correspondence Baudot, any code with eleven bits per character or less.

Information — Triformation Systems, Inc., June 1974.

30. Developer — Triformation Systems, Inc.
P.O. Box 127
Wall Street Station
New York, New York 10005, U.S.A.

Status — Commercially available, delivery 90 to 120 days.

Description — The LED-120 is a high-speed braille printer which can produce braille from a keyboard, from a computer, from magnetic cassettes or from almost any source of coded information. Speed up to 120 cps. Operating modes - EIA interface, TTY interface (other interfaces optional). Input code - ASCII, EBCD, BCD, Correspondence, Baudot, any code with eleven bits per character or less.

Price — $9000.

Information — Triformation Systems, Inc., June 1974.

31. Developer — Z. Weinberger
National Physical Laboratory of Israel
Hebrew University Campus
Jerusalem, Israel.

Status — Unknown

Description — A braille tape embosser produces braille cells on half-inch machine paper tape. By suitable interfacing, the brailler can accept input from computers, card readers, Telex tape and Monotype tape.

Information — Research Bulletin, No. 21, August 1970, page 118.

32,	Developer	W. A. Zawistowski Computation Centre Polish Academy of Sciences P.O. Box 22-00901 Pkin, Warsaw, Poland.
	Status	Prototype.
	Description	The tape reader-writer unit (type WAZA) reads 8-hole punched paper tape and outputs braille embossed on paper tape. Writing speed is 12 characters-per-second.
	Price	Circa $100
	Information	World Council for the Welfare of the Blind, Sao Paulo, August 1974.

33.	Developer	IBM Corporation Armonk, New York 10504, U.S.A.
	Status	Commercially available.
	Description	The printing mechanism on an IBM 1403 line printer has been modified to produce braille at about 250 characters-per-second.
	Price	Dkr. 550,000.
	Information	J. Vinding, September 1974.

REFERENCES

American Systems, Inc. *Arts Equipment and Services.* 123 Water Street, Watertown, Massachusetts 02172, USA, Nov. 1973, 21 pp.

Anderson, G. B. & Rogers, D. W. *An inexpensive braille terminal device.* Communications of the Association for Computing Machinery, Vol. 11, June 1968, 417, 418, 440.

Association de Nederlandsche Blindenbibliotheek. *Provision of braille reading-matter by means of punched tapes.* Noordwall 7, The Hague, Holland, 1973, 15 pp.

Boyer, J. J. *Brailletran: A comprehensive braille transcription program.* Proceedings of the Braille Research and Development Conference. Cambridge, Mass.: Massachusetts Institute of Technology, November 1966, 10-13.

Boyle, J., Jacobs, W., & Loeber, N. A braille code for interactive terminal use. American Foundation for the Blind, *Research Bulletin No. 27*, April 1974, 267-72.

Branachk, H. & Brix, G. *Mashinenschreiben fur blinde und sehschwache: Ein lehrbuch fur den gruppenunterricht und zum selbststudien.* 1966.

Clarke & Smith Industries. *Clarke & Smith braille system.* Melbourne House, Wallington, Surrey, England, February 1974, 11 pp.

Coleman, P. W. F. Computer terminals for the blind. *Electronics and Power*, March 1972, 18, 84-86.

Dalrymple, G. F. *Comparison of university of Dayton and MIT one-cell braille codes.* Sensory Aids Evaluation and Development Center. Cambridge, Mass.: Massachusetts Institute of Technology, Report No. 49, September 1970.

Danish Association of the Blind. Proceedings of the workshop, Computerised braille production. Copenhagen, September 1974, to be published.

Dinius, G. *Beitrag zur bestimmung der dv-funktionen und ihrer zuordnung zu funktionstragern und darauf aufbaunde konzeption zur erschliebung von blindenarbeitsplatzen in der edv.* Dissertation, Technischen Hochschule Aachen, Germany, 1971, 266 pp.

Eickenscheidt, B. *The braille translation program of Munster university.* The Munster Workshop, March 1973.

Forbes, J. Braille translation: The computer aids the blind. *Mitre Matrix*, 1972, 5(2), 22-31.

Foulke, E. Computer services for the blind. *The Braille Monitor*, May 1972, 207-10.

Gerhart, W. R., Millen, J. K., & Sullivan, J. E. *Dotsys III: A portable program for grade 2 braille translation.* Mitre Corporation, 1971, 139 pp.

Glaser, E. L. *Small computers and grade 2 braille.* Proceedings of the Braille Research and Development Conference, Cambridge, Mass.: Massachusetts Institute of Technology, November 1966, p. 14.

Goldish, L. H. *Braille in the United States: Its production, distribution and use.* New York: American Foundation for the Blind.

Grunwald, A. P. A braille reading machine. American Foundation for the Blind, *Research Bulletin No. 16*, May 1968, pp. 73-78.

Grunwald, G. M. *Prospects for utilization of compositors tape in the production of braille.* Argonne National Laboratory, 1971.

Final Report to John A. Hartford Foundation. *Development of a high-speed brailler system for more rapid and extensive production of informational material*

for the blind. Cambridge, Mass.: Sensory Aids Evaluation and Development Center, Massachusetts Institute of Technology, September 1970, reprinted 1973, 54 pp.

Ingham, K. R. *Spelled speech as an output for computers and reading machines for the blind.* IEEE Transcript HFE-8, No. 3, September 1967.

Ingham, K. R. *Braille, the language, its machine translation and display.* IEEE Transcript MMS-10, No. 4, December 1969.

Ingham, K. R. *A speech read-only memory store for blind programmers.* IEEE Transcript BME-17, No. 2, April 1970.

Kamp, H. *Gaining production rules for a Markov braille translation algorithm.* The Munster Workshop, March 1973.

Leffler, L. C., & Prastein, S. M. *The Argonne braille translator.* Argonne National Laboratory, Technical Memorandum No. 180, May 1969.

Lichtenstein, M. The Medcomp Braille Program. *Computer work for the blind.* Cincinnati, Ohio: College of Medicine, University of Cincinnati, September 1963, pp. 23-27.

Loeber, N. C. *Proposed braille computer terminal offers expanded world to the blind.* Conference Proceedings of the American Federation of Information Processing Societies, Vol. 39.

Mann, R. W., & Gammill, R. C. *Automating braille translation and presentation.* In: *Evaluation report on work in progress on sensory aids and prosthetics,* Department of Mechanical Engineering, Massachusetts Institute of Technology, Report No. 9211-2, April 1964.

Massachusetts Institute of Technology. *Proceedings of braille research and development conference.* Sensory Aids Evaluation and Development Center, November 1966.

Massachusetts Institute of Technology. *Proceedings of the conference on new processes for braille manufacture.* Sensory Aids Evaluation and Development Center, May 1967.

Massachusetts Institute of Technology. *Proceedings of the conference on new processes for braille manufacture.* Sensory Aids Evaluation and Development Center, February 1968.

Mick, D. E., & Hittinger, G. N. An inexpensive, universal braille (UNIBRL) output device. *Research Bulletin No. 24*, March 1972, pp. 158-160.

Millen, J. K. *Choice of cobol for braille translation.* Mitre Corporation, December 1969, 19 pp.

Millen, J. K. *Dotsys II: Finite state syntax-directed braille translation.* Mitre Corporation Report No. 1829, 1970, 43 pp.

Morrison, R. E. Braille embossing and transmission equipment. American Foundation for the Blind, *Research Bulletin No. 22*, December 1970, pp. 71-82.

Nemeth, A. *Recent developments in computerized mathematical braille.* Proceedings of the Conference on New Processes for Braille Manufacture, Massachusetts Institute of Technology, February 1968, pp. 50-53.

Parsons, J. L. *Computer program to translate inkprint to grade 2 braille.* Department of Engineering, University of Warwick, England, 1972.

Pearson, P. J. *Tactile music score.* Department of Engineering, University of Warwick, England, 1974.

Schack, A. & J. *Computer conversion of compositors tapes to grade 2 braille.* Proceedings of the Braille Research and Development Conference, Massachusetts Institute of Technology, November 1966, pp. 44-74.

Schack, A. & J. *Studies in the automation of braille mathematics and music.* Final Report to the Department of Health, Education and Welfare, The American Printing House for the Blind, June 1969, pp. 8-78.

Schack, A. S., & Mertz, R. T. *Braille translation system for the IM 704.* New York: IBM Data Systems Division, Mathematics and Applications Department, 1961, 66 pp.

Siems, J. R. *Report of new braille translation program at APH.* Proceedings of the Conference on New Processes for Braille Manufacture, Massachusetts Institute of Technology, February 1968, pp. 5-10.

Slaby, W. A. *A universal braille translator.* The Munster Workshop, March 1973.

Smith, G. W. The ARTS system. *Braille Forum*, November 1972, 11(3), 14-17.

Sullivan, J. E. *DOTSYS III: A portable braille translator.* Proceedings of the Association for Computing Machinery, 1973, pp. 398-403.

Sutherland, N. B. *Development of a dynamic braille display.* Mitre Corporation, Report MTR 1951, September 1970.

Thornhill, D. E. Translation from monotype tape to grade 2 braille. American Foundation for the Blind, *Research Bulletin No. 5*, July 1964.

University of Munster, Proceedings of the Workshop. *Towards the communality of algorithms among braille transcription systems for multilingual usage.* Munster, Germany, March 1973, to be published.

Valery, N. Computer tutor for shorthand braille. *New Scientist*, February 10, 1972, 319.

Vinding, J. *Modern methods of transcribing and printing braille.* European Braille Conference, Oslo, September 1973, pp. 10-12.

Vinding, J. *Braille printing program system description.* Copenhagen: Dansk Blindesamfund, Computerised Braille Production, 1974.

Vinding, J. *Braille translation program system description.* Copenhagen: Dansk Blindensamfund, Computerised Braille Production, 1974.

Werner, H., Dost, W., & Seibt, P. Automatic translation of inkprint to braille by electronic data processing systems. American Foundation for the Blind, *Research Bulletin No. 14*, March 1967, pp. 99-108.

Werner, H. *The historical development of automatic braille production in Germany.* The Munster Workshop, March 1973.

Windebank, C. L. Computer-produced braille. *Data Systems*, November 1968, pp. 18-21.

Wolfson Industrial Automation Group. *Braille computer terminal: A feasibility study.* Department of Production Engineering and Production Management, University of Nottingham, England, 1974, 13 pp.

Wolfson, R. G. *System study of electronic braille reproducer: Final report to Veterans Administration prosthetic and sensory aids service.* June 1961. New York: Adelphi Research Center, 1961, ARC Report No. 101.

Woodcock, R. W. *Development of an electromechanical braille transcribing and reproduction system.* George Peabody College for Teachers, Nashville, Tennessee, May 1965.

Woodcock, R. W. *Braille research at George Peabody College.* Proceedings of the Braille Research and Development Conference, MIT, November 1966, pp. 20-28.

Woodcock, R. W. An electromechanical brailling system. *Research Bulletin No. 21*, August 1970, pp. 101-107.

COMPUTER BRAILLE SYSTEM

Don Keeping

Editor's Note. The following description of the Computer Braille Service, Computer Center, The University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2--which prepares texts in braille for the Manitoba Department of Education--was written for us by Professor Donald Keeping, the supervisor of the service. The Center and Professor Keeping are also currently engaged in the development of algorithms for handling multi-language transcription of ink print into braille.

STAFF ORGANIZATION

1. Supervisor of project

2. Assistant Supervisor

3. Text analysts (part-time and full-time) divided into groups of three or four persons each. Each person in a group is responsible for transcription of one book and is assisted in various stages of transcription by other members of the group.

4. One part-time person to help to run the brailler, to do proofreading in braille, tearing and collating of pages.

5. One part-time person to document, maintain, and improve the system's programs.

TRANSCRIPTION OF BRAILLE BOOKS

Upon arrival, a book is assigned to a text analyst who will analyze it with respect to tab settings, identification of pictures, tables, and diagram handling. A preliminary report is made and after meeting with other members of the group and the assistant supervisor to discuss length of volumes, format, etc., the report is completed. In addition to format, the report might contain proposed braille volume length (average number of cards per braille volume is approximately 850 cards, or from 5-3/4 to 6-1/4 inches). Volume size depends to a large extent on content.

The analysis is referred to at every stage in the preparation of the book including keypunching, proofreading and correcting. If it becomes necessary during this operation to deviate from the rules set out in the analysis, another group consultation is held, and the analysis retyped.

Reports of the various stages in the preparation of each volume are made at the end of each working session.

PRODUCTION OF BRAILLE VOLUME

Key punching is done by any member of the group. Data is keypunched on cards and from the viewpoint of the keypunch operator (text analyst), is to be considered as one continuous stream; that is, column 80 of one card is continuous with column 1 of the following card.

Preparation for braille transcription necessitates modifications in the text which are made in two ways:

1. Modifications in the text itself by the keypunch operator.

2. Modifications carried out by the DOTSYS program under the direction of commands beginning with a dollar sign interspersed throughout the text. These $ commands must be inserted by the keypunch operator.

The keypunch operator is also responsible for setting up proper braille volume lengths according to the specifications mentioned above. Volume headings and footings should be inserted.

From Cards to Disk

From here on, the system is operated through TSO (Time Sharing Option).

When keypunching is completed, cards are put into an OS data set. The data is then run through a program "Cutdown," the function of which is to cut down the length of each record from 80 columns to approximately 50-55 columns. It also eliminates words which run over more than one card, and renumbers the data set and outputs it on the printer.

Backup

All of the OS files containing Dotsys text are backed up on tape. This is a single-file tape containing a copy of all the current Dotsys text files. It is updated once a week, or when any major change is made in the current Dotsys text such as several new volumes being added. When it is ascertained that the volume is backed up, the original cards are deposited in a retaining drawer for one week, at the end of which time they may be destroyed. In case of loss, a Dotsys text file may be retrieved from the tape. The Copy program inserts all current files together into a single OS data set. The lost file may then be isolated and retrieved with the Edit Command of TSO.

First Proofreading

The listing is proofread very carefully. Errors are noted and the corrections inserted in a clear and legible manner. Format commands are extremely important. A clear understanding of the rules of modification is absolutely necessary before any attempt at proofreading is made.

The following notes to the proofreader are part of a short training course given to each of the text analysts before they attempt work on any book.

> "Do not assume that a keypunch operator knows the rules better than you do.
>
> Do not leave errors for future proofreaders to correct.
>
> If you do not understand an item in the listing, question the Assistant Supervisor or the Supervisor.
>
> Do not leave a 'known' error in the text."

First Corrections

Corrections are made through TSO at a computer terminal. The individual Dotsys text files are made available through the Edit Command. This Command allows changing of text, insertions, deletion of text, and replacing of incorrect lines.

Second Proofreading and Corrections

The procedure for second proofreading and corrections is a repetition, although a very important one, of the first proofreading and corrections.

At the end of each session of keypunching, proofreading, or corrections, an entry is made on the current book report for this book giving information as to the current stage of the work on the volume. This log is extremely important and is always kept up to date.

Final Look

After the second corrections the Dotsys text file is run against a program "Look." The function of this

program is to check for errors in $ commands, format, etc. The output of this program is a list of errors found in the text, along with their line numbers. If there are any errors, another correction session will be necessary.

BRAILLE TRANSACTION

At this point, the text should be ready for brailling. The transcription is done through two computer programs, "Dotsys" and "Return." The final output from these programs is an OS data set which contains the text in braille format, that is, the lines are 39 columns long and 25 lines-per-page and contain braille contractions. This file is then run through the Triformation LED-120 or the MIT Braillemboss. The braille pages are burst and the perforated edges removed. They are then sent to the University of Manitoba Central Printing and Duplicating for binding. The braille book is then labeled in ink print and braille, and delivered to the student.

STORING DOTSYS TEXT

When the volume has been brailled, the Dotsys text file is transferred to a magnetic tape. These tape files accumulate and become the backup for the system. They are the sources from which copies are made, and are also used as the basis for corrections if the student finds errors in his text. Every two weeks a duplicate of the magnetic tape files is made, and kept in the office.

CATALOGUING THE BOOKS

When a book is accepted for transcription into braille, an entry is made in a text data set to include the following information: author, title, publisher, date of publication, number of braille volumes, subject, and a code indicating that this is a braille book done at the University of Manitoba. The output from the program is a list of the current books, as well as those already transcribed, sorted either by title or author. Copies are neatly bound and are available to anyone.

AIDS FOR THE SPEECH-IMPAIRED: INTERNATIONALLY COORDINATED DEVELOPMENT WORK

Birger Roos

Editor's Note. The following description of a forthcoming international cooperative research program in development of aids to the speech-impaired seems important to us as a model for such undertakings, quite apart from its intrinsic importance; hence our inclusion of the details in the Bulletin. In a covering letter written by Karl Montan, Director of the International Society for the Rehabilitation of the Disabled's Committee on Technical Aids, Housing, and Transportation, it is noted that:

> "It is of extreme importance that ICTA is able to build up models for international cooperation in different activities concerning technical aids for the disabled. NVR in the Netherlands has contributed to such a model as far as building norms are concerned.
>
> "Handikappinstitutet in Sweden is now offering another possibility to create an international model for research and development in near cooperation with ICTA. This case concerns a study of technical aids for persons with speech impairment (see attached project plan).
>
> "Very early in the study we will have to find out what is going on in this field in other countries. For this purpose we will later on prepare a systematic inquiry but we are already now eager to hear your reaction to the project. If you know of any institutions, scientists or private firms interested in this field, please let us know."

We concur with these sentiments, and we are sure that our readers will also. Inquiries about the project might be best directed immediately to Birger Roos at the Handikappinstitutet, Fack, S-161 03 Bromma 3, Sweden.

BACKGROUND

Persons who for different reasons have their speech capacity impaired, have presently very limited access to technical aids that may compensate for their handicap and make the individual less dependent upon the assistance of other persons. The present application for financial support in this area of technical aids aims at trying to remedy this. Considering the fact that the speech-impaired have considerably different needs, depending upon the nature of the impairment, the number of persons in each group in need of a certain type of aid is relatively small. These circumstances make production of new products difficult. The Swedish Institute for the Handicapped, therefore, wishes to investigate the field of aids for the speech-impaired on an international basis. This intention has previously been declared in a letter of February 13, 1974 to the Swedish Board for Technical Development. The appropriateness of international activity in this field has also been mentioned in "Memorandum Concerning the Activities of ICTA" (1972-02-08).

The project is calculated to run for three years at a total cost of

304,000 Swedish crowns, in addition to which there will be costs for external investigations of 50,000 crowns at most.

PROJECT DESCRIPTION

Handicap Groups

Speech-impaired persons form a heterogeneous handicapped group that is still unknown both in number and in type of impairment. The following groups may be of interest to the project.

Phonation-impairment. Persons with phonation impairment have a reduced function of the vocal cords and thus have difficulty in producing a vocal tone useful for speech. One group of these is the laryngectomized who due to an operation in the larynx completely lack vocal cord function. This group comprises approximately 500 persons in Sweden. (The population of Sweden is approximately 8 million.) For them, there exist certain tone-generating aids to be applied outside of the throat, or in the oral cavity. These aids should be developed and complemented with others. The number of other persons with vocal cord problems, such as a weak voice, is very little known as well as the need of aids for these persons.

Stutterers. Problems with stuttering are relatively widespread, but may differ in character. Certain aids for stutterers have been developed in various places in the world but have not been put into production and have thus not reached wide distribution.

Articulation-impairment. Articulation-impaired persons are those with a reduced mobility and coordination ability of the moving parts of the speech organ; the lips and tongue. The injury may be congenital or acquired, following a hemorrhage. One investigation has estimated the number of articulation-impaired persons in Sweden in possible need of an aid at between 2000 and 3000 persons. For these there are no known aids beside conventional typewriters.

Delayed development of speech. Due to the retardation or deafness, the development of speech may be delayed. Persons with speech difficulties due to this reason form a very heterogeneous group and the situation for aids is not clear. This group in particular requires suitable training aids. Certain aids have been developed at the Department of Speech Communication, Royal Institute of Technology, Stockholm.

Language-impairment. Speech difficulties may also be caused by a reduced function of the speech center of the brain. Such an impairment is called aphasia and is often combined with other impairments. The need for aids has not been investigated.

The Aid Situation

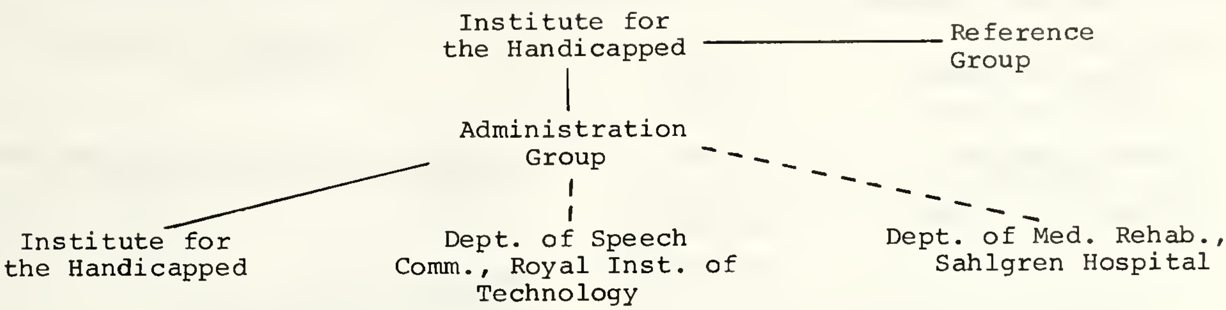
As shown, the access to aids for speech-impaired persons is not satisfactory. It is known that individual aids have been developed in several parts of the world. However, they are not very well-known and there exists no collected information on work in the field. Considering this fact and the fact that speech-impaired persons form a relatively small handicapped group in each country, investigation work in the field should be carried out on an international basis.

Project Organization

The Swedish Institute for the Handicapped, therefore, suggests an international project to investigate the aid situation for speech-impaired persons, organized on the lines of an international reference group with a Swedish secretary, employed by the Institute. The project is calculated to run for three years, of which the last year to a great extent will be devoted to the creation of a permanent organization, intended to work subsequently in close contact with the Institute and ICTA. In the first period of the project a Swedish administration group for detail planning with representatives from the Institute, the Department of Speech Communication, Royal Institute of Technology, Stockholm, and the Swedish Board for Technical Development will

be established. Furthermore, the Institute for the Handicapped will organize a Swedish reference group with representatives from different specialties in the field, such as speech transmission, phoniatrics, linguistics, and neurological rehabilitation.

The project slated to begin in the Fall of 1974 will be constructed accordingly:



Project Work

The work will include the following:

1. Survey of the speech-impairment.
   a. Type of impairment, diagnosis, symptoms.
   b. Number of persons and distribution.
   c. Need for aids, physical and mental prerequisites.
2. Survey of the situation for technical aids (including training aids).
   a. Existing aids; testing, judging.
   b. Present development work.
   c. Desired development work.
   d. Prerequisites for initiation of development work.

Apart from the work of the secretary and the reference group, certain special investigations will be ordered from consultants, such as persons with phoniatric education. As an example of such investigations, an analysis of the ability of certain speech-impaired persons to manage writing equipment, need for access to a word memory, and need for different kinds of presentation (writing, synthetic speech, etc.) may be mentioned.

The project work is estimated to run according to the following schedule:

1. Establishing project organization and Swedish reference group (year 1).
2. Existing documentation (year 1).

   Collection and studies.

   Creating a documentary system.
3. Present activities (year 1-2).

   Inventory by inquiry.

   Studies by visits to foreign institutions concerned.
4. Establishing an international reference group (year 2).
5. Symposium and work plan for the future (year 2).

   Outline of a work plan for the future.

   Outline of an international symposium and exhibition.

   Symposium in Sweden.

   Work plan for the future.

6. Permanent organization (year 3).

Establishing period.

Steady state.

Costs

The costs for the project are calculated for year 1 to a total of 82,000 Swedish crowns according to the following calculation:

Secretary	
Salary, 10 months	40,000
Social expenses	12,000
Travel expenses	15,000
Documentary system	15,000
	82,000

In addition to this there will be external investigation work as mentioned above at a total cost of 50,000 crowns maximum. For years 2 and 3 the costs are calculated at 111,000 crowns per year due to increasing expenses for salary and travel.

ASSOCIATED PROJECTS

The following projects will be associated with the activities of the Swedish Institute for the Handicapped.

The Department of Speech Communication, Royal Institute of Technology, Stockholm

At the Department of Speech Communication a project in this field has been running for four years. It is divided into two parts:

1. Aids for phonation-impairment. Development of amplifier and vibrator with different types of frequency and amplitude control.

2. Aids for articulation-impairment. Technical investigations concerning hand-maneuvered speech synthesis equipment and writing equipment with word memory.

The following persons are working within the project:

K. Kalyas, project leader

P. Branderud, technical development

L. Bondelind, technical development

The bulk of the work has been concentrated so far on part 1.

The Department of Medical Rehabilitation, Sahlgren Hospital, Gothenburg

At the Department of Medical Rehabilitation in Gothenburg for the past year work has been in progress on writing equipment for persons with anarthria; that is no speech ability due to injury of the cranial nerves and/or the nerves controlling the mobility of the tongue. For these persons special writing equipment consisting of a keyboard and a display unit has been constructed. The equipment has been received very positively by the handicapped, hospital staff, and others. It has been determined that a valuable feature would be for the equipment to present whole words by pressing single keys. The speed of the system would be thereby increased substantially. Future work on the equipment will thus aim at providing the system with a memory. The work is led by Dr. Bengt Lindberg.

ASPECTS OF SOME PROBLEMS RELATING TO THE TRANSLITERATION OF THE HAUSA LANGUAGE INTO BRAILLE

James I. Murnane*

The subject was first suggested early in 1973 by Dr. D. J. M. Muffett, Assistant Professor at the Institute of African Affairs at Duquesne University. He recalled a former blind American student who was studying Hausa and for whom a pilot braille system had to be developed by the Institute in cooperation with volunteer workers of the Rodof Sholom Congregation in Pittsburgh. A more detailed examination of some of the problems which arose then seemed clearly indicated.

NEED ESTABLISHED

A further impetus arose when Alhaji Tijani Malamfashi of the Military Governor's Office in Kaduna, Nigeria, undertook to interest the Federal Government of Nigeria in the prospects of a transliteration of the Hausa language into braille, especially for Nigerian ex-servicemen blinded in the Civil War (1966-70). His observations confirmed that although there are presently well-developed institutes for the blind in Northern Nigeria, rehabilitation does not as yet include substantial programs for the Hausa-speaking blind. None of the necessary groundwork for a braille system appears yet to have been undertaken. Further confirmation of this view has come from the Principal of the Nigerian Army Blind Centre in Kaduna, Captain Waziri Mahdi.

An opportunity would, therefore, appear to exist for developing a program based on the research reported here, optimizing its potential for assisting in the rehabilitation of the blind in considerable numbers. Beyond the initial inquiry a great deal of research still remains to be done--and it is clearly not merely highly desirable, but in fact quite imperative, that it should be done in Nigeria.

During the summer of 1973 some experiments were conducted on certain of the problems expected to arise during practical attempts at transliteration. We were aided by a blind American teenage girl who was fluent in braille, but who had no previous experience whatsoever in Hausa or in linguistics. With the aid of a pilot series of designators, however, she was able to reproduce the appropriate phonemes with a more than reasonable degree of adequacy, except for an occasional minor variation in tonality. It thus became clear that further work with a Hausa-speaking instructor and a language laboratory could readily correct this deficiency. This same problem would not confront a blind Hausa speaker, of course, any more than it would confront a sighted Hausa speaker learning to read in Roman characters.

The research into the problems arising from Hausa transcription into braille was continued. The thesis presents some of the major aspects of these problems, together with proposed solutions for them. The study appears to be unique, since no African languages as yet appear to have been subjected to such an analysis and examination.

*Duquesne University, Pittsburgh, Pennsylvania.

Since the advent of colonialism, Islamic institutions which formerly had provided for the maintenance, assistance, and rehabilitation of the blind seem to have dwindled away. Sporadic attempts have been made to rehabilitate selected persons, some by national movements (such as the Nigerian Federal Government), some by Christian missionary groups or by the *Ahmidiyya* of Islam; others along multidenominational lines usually under the auspices of philanthropic societies, such as the Royal Institute for the Blind in Britain (which has been active in Hausaland, and established a Northern Nigerian Society as early as 1952). None of these attempts, however, have so far considered the problems created by attempts at vernacular transliteration.

THE HAUSA LANGUAGE

Hausa is a major language not only in Nigeria, but also throughout West Africa. It is spoken as a primary and secondary language, or as a commercial *lingua franca*, by many millions of persons in Northern Nigeria, Niger, Northern Dahomey, Northern Ghana, Northern Togo, Cameroons, Upper Volta, Chad, and the Sudan. According to BBC statistics, it may be shared by as many as 100,000,000 people. It is a well-established written language. It was transcribed in *Ajami* (Arabic script) centuries ago, although its transcription into the Roman alphabet dates only from about 1910. Clearly, Hausa will not lose its status as a major language of West Africa within the foreseeable future.

BLINDNESS IN THE LANGUAGE AREA

Meaningful statistics on blindness in Hausaland are not easily obtainable. Those most readily available, contained in *Annales d'Oculistique*, state that 0.8 to 1.0 percent of the population in Northern Nigeria is blind. Of the 25,000,000 or so people in this region, at least 22,000,000 may be regarded as competent in Hausa for the purposes of this project, and it can thus be estimated that there may be at least 200,000 blind Hausa speakers in Northern Nigeria alone.

In the Hausa language area, the most significant cause of blindness are, in their order of prevalence:

1. Onchocerciasis,
2. Trachoma and trichiasis,
3. The prurulent keratides (following smallpox, measles, and even chickenpox),
4. Cataract,
5. Eye injuries.

Greatly increased efforts have been undertaken recently by the Nigerian Federal Government to rehabilitate the blind, although as yet there has been no attempt at the structured establishment of a system of braille for the Hausa-speaking blind.

However, the situation is much more desperate for the blind Hausa speakers living in Francophonic West Africa. In this region (Upper Volta, Niger, Chad, Dahomey, Togo, Cameroons), the worst endemic area in the world for onchocerciasis, there appear to be no rehabilitation programs for the blind at all.

A BRAILLE SYSTEM

Certainly, it would be naive to expect that the majority of these persons can be made readers of braille. Possibly, only between 15 and 30 percent of 200,000 blind Hausa-speaking Nigerians (75,000) could become proficient. However, even if only that number of persons can be helped, then the contributions which they would make to the nation would be enormous. And although all the results of the system may not be put to utilitarian purposes, its adoption would at the very least assist in putting an end to the terrible physical and social isolation which blind people suffer--which constitutes the major tragedy of the affliction.

The proposed Hausa braille system will conform as much as possible with the English model, should a blind Hausa speaker desire to study English after having mastered the Hausa system.

It is recognized that there is a French phonetic system for *Haoussa* which is used in Francophonic West Africa. In Niger alone, there is a population of 1,800,000 Hausa whose phonetic experience in the language has been essentially Francophonic; but *Haoussa* in such localities has survived for all practical purposes as an oral language, and French is always the official tongue. In any case, the English phonetic system of Hausa would obviously be entirely intelligible to the Francophonic blind Hausa since the probability of his being illiterate is overwhelming and his instruction would thus take place *ab initio*. However, the divergence between the French braille system and the proposed Hausa system would be considerable, as a number of unique French phonemes are to be deleted in the latter system.

In the proposed Hausa braille system,

1. The entire Roman alphabet and the number system, qualified by the numeral sign, must be maintained. Although the letters Q, V, and X do not occur in Hausa, and P is vestigial, it is necessary to retain these letters in case the blind student should desire to learn English braille at a later date.

2. The punctuation is to be retained for the most part. Exceptions are in the separation of the English braille symbol for the open quotation mark from the quotation mark, which may have led to some confusion; and the association of the Hausa particle *KO*? and *TO*! (with the question mark and the exclamation mark, respectively). In the Hausa system, one braille symbol will represent the quotation marks.

Other changes include the introduction of addition, multiplication, and subtraction signs; a Hausa equivalent of "italics" is substituted; and the glottal stop is associated with the English symbol for the apostrophe.

It must be mentioned that Hausa punctuation is not presently as sophisticated as English punctuation, although in the future it is believed that it will become more complex.

3. The essential Hausa phonemes B, D, and K must be represented, and the nonessential, but significant, phonemes *TS* and *SH* will be included.

4. A number of syntactical peculiarities should be represented in the adaptation of braille to the Hausa language. Among these are the conjunction (*DA*), identifiers (*NE*, *CE*, and *KE*), locators (*GA* and *MAI*), negative (*BA*), the preposition and conjunction (*SAI*), and the future particle (*ZA*).

5. All of the English "wholewords" have been deleted, except for the Hausa correspondent of "and" (the conjunction *DA*). Similarly, all the English "partwords" except the phoneme (SH) have been dropped.

The Hausa braille system may be developed even further with the assignation of "wholewords" to the letters, as in the English system. However, such future changes must await considerable research into frequency of usage and testing in the field.

It is believed that this Grade 1-1/2 braille scheme can minimize the space needed without obscuring the readability of the text.

Hopefully, all of the problems in this first transliteration attempt have been solved, although of course the final determinant of the validity of each braille symbol will be ascertained in the field study in Nigeria.

BIBLE TRANSLITERATIONS

It has been reported by Captain R. White, Deputy Director of the Royal Commonwealth Society for the Blind, that some braille transliterations of the Hausa language already do exist. However, further inquiry showed that the documents in question are transcriptions of the Christian Bible, and are used in "Vernacular Bible Schools." These materials would be of minimal interest to the Hausa-speaking blind, the vast majority of whom are Muslim. Furthermore, the dissemination and implementation of these braille tracts have been forestalled by contradictions among the three different braille

systems used by proselytizing groups. For example, the transliteration of the Christian Braille Ambassadors is not compatible with that of the Lutheran Braille Workers, nor that of the Scripture Gift Mission. Regrettably, an official at the Sudan Interior Mission School for the Blind was unable to determine who compiled the respective systems, or account for the divergence of braille symbols.

CURRENT USE

Captain White's colleague in Nigeria, Austen N. Chibututu, Administrative Secretary of the Social Development Division of the Federal Ministry of Labour, has asserted that Hausa braille is in use in ". . . Residential Schools for the Blind as well as in the Open Education Scheme for the Blind in the Hausa-speaking areas of Nigeria." Unfortunately, no details concerning these institutions have been found to conform or amplify this statement. There is thus some doubt as to whether or not a secularized use of Hausa braille, at either Grade 1 or Grade 1-1/2 levels, already is current in Nigeria, or the extent of its use, if any.

Because of such contradictory information on this point, therefore, the exact status of Hausa braille cannot readily be determined. At best, its implementation would appear to be extremely limited, since opinion on it leads to some contradiction between officials in the Military Governor's Office (whose information on the situation at the Nigerian Army Blind Centre must be considered to be substantially reliable) and that of a Federal official in the more remote Social Development Division in Lagos (although his information must of course be taken seriously). To resolve this matter, further on-the-spot inquiry will be necessary.

The response of some of the blind rehabilitation workers at the Institute for the Blind in Albany, New York, to the prospects for such a program has been mixed. We were reminded that presently only about 5 percent of the blind in the United States today are fluent in braille--a figure which is startling in its limitation--and that this low percentage was due in part to extensive reliance on electronic aids, including radios, phonographs, tape recorders, the Optacon, and talking books. Such equipment, however, would be prohibitively expensive for the vast majority of Hausa speakers, whereas braille documents would not, especially if their circulation were to be subsidized by the Federal Government. Conceivably, therefore, the proportion of blind Hausa-speaking persons who would become literate in braille might be expected to be very much higher than that reported for the United States.

One blind rehabilitation worker placed considerable stress on the fact that the social environment of the blind person would counteract the attraction of literacy to them. Her concern was based on experience in a program for the introduction of a Spanish braille system in rural Mexico. In that setting, there was considerable resistance to the introduction of braille on the part of the community, which was principally illiterate, as well as by blind subjects, who likewise had little desire to become literate, and who refused to act independently of the local mores. Rather, the blind preferred that others help them and approve the relatively limited scope of their daily activities. The community did see, in fact, that blind persons were not completely neglected, and assured that at least minimal needs were taken care of.

There might be some resistance to changes in "traditional" Hausa attitudes toward the blind at the present moment, but the modernizing elements in the culture ought to demonstrate a compensatory receptivity. This should be so especially in view of expressions of concern over blind beggars which some government officials have voiced already.

Without doubt, the blind could only benefit from literacy, even if they were only to attain a minimal understanding of basic mathematics for simple personal transactions, or in using braille labels. Its introduction is essential for the primary education of young blind persons (or for its continuance) and, in the case of the Hausa of Northern Nigeria, it is especially important as a tool in the meaningful rehabilitation of blind war veterans.

To some extent, a knowledge of braille would free the blind from their absolute dependence on members of the local community. The family and the local community may continue to maintain and assist the blind, but this will be only at the present level of deprivation. Any increase in productivity or standard of living of the blind will entail wider involvement than local initiative can provide. Furthermore, as Nigeria becomes increasingly modernized and urbanized, the task of coping with the blind population on the present basis will undoubtedly become increasingly more burdensome for the nuclear or the extended family, as has been the case everywhere. For these reasons, blind persons may have eventually to assume greater responsibility for their own independence. It is to their long-term advantage, therefore, to take advantage of and to adapt to the best facilities for rehabilitation that can be made available.

BLIND PROGRAMMERS AT ROLLS ROYCE — NEWSLETTER 1, JULY 1974

Terry Tate*

Editor's Note. The increasing number of enquiries about the Rolls-Royce program to train and utilize visually impaired personnel in its data processing activities prompted Terry Tate to compile the first issue of a Newsletter on their work. He has very kindly given us permission to reproduce it for readers of the *Bulletin*, allowing us to bring it to the attention of a yet wider audience of interested persons. Further issues of the Newsletter will be republished here as they appear.

This newsletter is produced in response to the increasing interest being shown in our activities in the field of the visually handicapped. As this is our first issue, we have included some items of historical interest for the benefit of those who may not be aware of our experience in employing blind programmers.

Terry Hicks began to lose his sight while serving a company apprenticeship as a production engineer. He joined the Engineering Computer Centre as a trainee programmer in 1970. He is now competent in a number of languages, low and high level, and has attained the rank of Senior Systems Programmer.

Ian Dawson was educated at Worcester College for the Blind and subsequently gained an honours degree in Mathematics at Lanchester Polytechnic. He joined the Computer Centre is November 1973 and following training, is now a member of our Numerical Analysis Group.

We took delivery of an M.I.T. BRAILLEMBOSS in 1971. Connected on-line to our computer complex (AMOS), this device parallels the operation of a normal teletype but produces paged BRAILLE instead of normal print. Thus our blind programmers are provided with the same on-line computing facilities as their sighted colleagues.

Languages used in the centre include FORTRAN, KDF9 USERCODE, PDP10 MACRO and a number of special purpose in-house autocodes. The system offers interactive and batch operating features. Our two KDF9's are to be replaced by one CYBER 74 in 1975.

We have produced a grade II BRAILLE translator (written in MACRO10).

A special purpose line formatting programme (DOT) overcome certain limitations of the BRAILLEMBOSS.

Other enhancements include a modification to substitute Standard English Computer BRAILLE for the American equivalent, which the BRAILLEMBOSS originally output, and the provision of a switch to suppress the output from the teletype, if desired.

After two years of virtually trouble free operation, we have had some difficulty with the BRAILLEMBOSS recently, due mainly to worn parts, but thanks to prompt assistance from MIT and the efforts of our engineers, our problems have largely been overcome.

We are giving a presentation to the British Computer Society on October 16th 1974 entitled: "Blind Programmers in Computing."

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*Rolls-Royce (1971) Ltd., Bristol Engine Division, Engineering Computer Centre.

MISCELLANEOUS

ABSTRACTS OF LITERATURE ON CURRENT RESEARCH ON EDUCATION FOR THE VISUALLY HANDICAPPED

Michael J. Tobin

Editor's Note. Dr. Michael J. Tobin, Director of the Research Centre for the Education of the Visually Handicapped, University of Birmingham, Birmingham, England, initiated a service for British educators of the visually impaired some two years ago which extracted the substance of current research of interest to them. We thought the output of this unique service to be valuable to a much wider audience of users. We solicited, and received, permission from Dr. Tobin to reproduce these abstracts in the *Research Bulletin*. Although documentalists will be unhappy that the entries do not have descriptors nor other identifying terms, they will be cheered by the news that this data will be added when the material is entered into the forthcoming machine-readable Research Index that IRIS is in the process of generating. We plan to keep these entries up-to-date by publishing them as they are received from Birmingham. We welcome your comments on their utility, and, of course, welcome your additions or corrections, to the material published.

Akiyama, Y., Parmalee, A. H., Jr., & Flescher, J.

The electroencephalogram in visually handicapped children.

The Journal of Pediatrics, 1964, 65, 233-242.

The abnormal or unusual developmental behavioral patterns in visually handicapped children fail to identify causal factors or the nature of problems. In previous studies of EEG abnormality, no positive relationship between neurologic findings and behavioral or intellectual development has emerged.

The developmental charts and EEG's of 38 children with a variety of visual handicaps were studied. The greater the loss of vision, the more abnormal the EEG's, but no relationship was found between abnormal tracings and the occurrence of seizures or of retarded intellectual development. Abnormal EEG's are not indicators of a poor prognosis for behavioral development.

Anderson, G. B., & Rogers, D. W.

An inexpensive braille terminal device.

American Foundation for the Blind *Research Bulletin No. 22*, 1970, 111-117.

The active use of time-shared facilities for blind programmers requires a braille terminal system. Details are given for the construction of a brailler from a Model 33 teletype by modifying the print head and increasing the resiliency of the platen. A description of the programming needed to drive the brailler is presented. Possible improvements are discussed; it is concluded that the brailler has proved very effective in use, the braille being easy and convenient to read and the reliability of the overall system approaching that of a non-braille system.

Apple, M. M.

Kinesic training for the blind: A program.

Education of the Visually Handicapped, May 1972, 2, 55-60.

Seven congenitally blind adolescents from a residential school for the blind participated in a program of kinesics training (interpersonal communication expressed through movements of parts of the body) of 6 weeks duration, the purpose of which was to acquaint the subjects with common facial expressions and body gestures. Instruction was conducted both individually and in a group setting. Observations made of the experimental group and the control groups at the conclusion of the program revealed that the experimental group did *not* show a greater frequency of "test" gestures (i.e., new gestures learned during the program) than either the sighted or blind control groups. The author feels that the negative test results do not necessarily invalidate the program, however, difficulties in methodology and procedure could well be masking what may be an effective program for the congenitally blind.

Avery, C. D., & Streitfeld, J. W.

An abbreviation of the haptic intelligence scale for clinical use.

Education of the Visually Handicapped, May 1969, 2, 37-40.

The Haptic Intelligence Scale (HIS), which had been administered to 32 students at a residential school for the blind, was rescored for each subject using an abbreviated form of the test. Each of the 6 subtests of the HIS was rescored, but on 5 of the 6 subtests only 46 percent of the items were utilized; the 6th utilized 100 percent of the original items. Results indicated an almost identical distribution with that of the HIS, and a correlation of 0.99 between the 2 forms; 94 percent (30 out of 32) of the scores varied no more than 4 IQ points and the largest variation was 7 IQ points. The correlations between the 2 forms of each subtest were also found to be highly reliable. The results suggest that the abbreviated form of the HIS can be used with confidence both in the research studies of groups and in clinical evaluations of individual intelligence; the authors feel that the obvious advantage of the abbreviated form is its timesaving aspect.

Axelrod, S.

Severe visual handicap and kinesthetic figural aftereffects.

American Foundation for the Blind *Research Bulletin No. 17*, July 1968, 1-4.

Thirty-three severely visually handicapped (legally blind) high school students were compared with 33 normally-sighted students in amount of kinesthetic figural aftereffect (KFAE) at 0, 1, 2, 4, and 6 minutes after a 60-second inspection period. KFAE for both groups were negatively-accelerated decreasing functions of time since inspection. KFAE for the visually handicapped group were significantly smaller than for the controls. Differences due to degree of residual vision, age at onset of visual loss, and sex, were not significant.

Barraga, Natalie.

Increased visual behavior in low vision children.

New York: American Foundation for the Blind, 1964. 199 pp.

Through a controlled experimental approach to specialized teaching, braille reading children with low degrees of visual acuity (6/200 or less) were visually stimulated for a short period in an attempt to increase their visual functioning despite their assumed lack of usable vision. Highly significant gains in visual efficiency were demonstrated by all experimental subjects. Findings verified the validity of stimulation programs to enhance learning and suggested the need for continual appraisal of children in regard to appropriate reading media. A Visual Discrimination Test for measurement of visual abilities and detailed lesson plans for a stimulation program are included.

Bateman, B.

Reading and psycholinguistic processes of partially seeing children.

Washington, D.C.: The Council for Exceptional Children, NEA, 1963. 46 pp.

The purpose of the study was to investigate the effect of visual defect on the reading and psycholinguistic processes of children with a variety of visual problems. Instruments used were: Monroe Reading Examination, Illinois Test of Psycholinguistic Abilities; and the Stanford-Binet.

Little relation was found between the degree of visual defect, reading ability, and the intelligence of the children. Apparently, central processes are not grossly impaired by limitations on sensory input; therefore, a justified conclusion is--help each child use centrally what he has peripherally.

Bauman, M. K.

Clinical interpretation of personality inventories.

Education of the Visually Handicapped, (P. A. Vol. 49, No. 6, June 1973, No. 10240, Vol. 3(3), October 1971, pp. 82-87.)

Discusses the interpretation of personality inventories by clinical psychologists with special reference to the A.E.F.I. (Adolescent Emotional Factors Inventory), a measure of adjustment for visually handicapped adolescents. It is proposed that while factorial studies have their uses, the clinician works with individuals, not groups; he is concerned with the individual context (i.e. the personal history, interview data and other test results); and he interprets subscale scores as a configuration. The A.E.F.I. subscales and scoring system are briefly described. Five cases are described in which the interview data served as validating evidence for the A.E.F.I. subscale scores.

Beermann, U.

Visual exercises and sight education.

The Visually Handicapped, April 1972, 1, 15-16.

Since the turn of the century teachers in the field of the education of the visually handicapped have engaged themselves more and more in solving the problem of how the vision of the handicapped pupil can be increased. After the theory of saving sight had lost its dominant influence on education, special visual exercises with mainly medical character were introduced in many schools for the partially seeing. Partly these exercises corresponded with those of the sight training schools of Bates and called forth the criticism of ophthalmologists and educators. With the introduction of pleoptic and orthoptic schools for visual training the intersections between medical and educational fields of tasks advanced so far, that a clear marking off seems urgently necessary. Although the measures even partly resemble each other in the two scientific areas they show their own characteristic accents: visual exercises in pleoptic and orthoptic pursue the aim of a physical improvement in visual power; the educational exercises are primarily directed to improve the psychological components of the visual act. Special visual exercises therefore have a justified place in the education of the partially seeing. As its main aim, however, visual education is to be regarded as a principle of instruction, which means that in each lesson the efficiency of visual performance should be evaluated and stimulated as much as possible.

Benjamin, J. M., Benham, T. A., Bolgiano, D. R., & Meeks, E. D.

A laser cane for the blind.

American Foundation for the Blind, *Research Bulletin No. 22*, 1970, 139-142.

A collapsible, lightweight (1-1/3 lbs.) cane, incorporating a laser beam generator and receiving optics and photodiodes, is described.

The device emits pulses of infrared light in three beams to look simultaneously down, straight ahead, and upwards. The beams are reflected from any object in front of them and detected by a photodiode placed behind a receiving lens. The downward beam warns of any drop-off larger than nine inches at a distance of two paces in front of the traveler; a low-pitched tone notifies the user. The straight-ahead beam, about two feet high, warns of objects at a maximum (adjustable) range of out to twelve feet in front of the cane; warning is by means of a tactile stimulator on the index finger. The upward-looking beam detects obstacles at head height appearing directly above the cane tip, as earlier warning proved confusing; warning is given by a high-pitched tone.

Bentzen, B. L.

Production and testing of an orientation and travel map for visually handicapped persons.

The New Outlook for the Blind, 1972, 66, 249-255.

To test the hypothesis that a tactual map can facilitate independent travel by visually handicapped people in an unfamiliar area, six subjects, all proficient blind travelers, were provided with a tactual map of the campus of the Perkins School and asked to travel to each of three objectives. The map, designed to utilize symbols and criteria found effective by various researchers (Angwin; Leonard; Nolan; Shiff; and Wiedel) was constructed by hand and reproduced by thermoform, with the braille labels located on a tactual overlay. After training in map use, the subjects, all unfamiliar with Perkins School, were given points for reaching each of the three objectives in the allotted time, with points deducted for each "checkpoint" along the route which was missed or each wrong turning made. Of a total possible score of 27, the range of scores was 15-22 and the mean score was 19.1. All subjects succeeded in reaching all three objectives within the time limit. Reactions to the map by the subjects indicated that, for a variety of reasons, each found it preferable to verbal directions.

Berla, E. P.

Effects of physical size and complexity on tactual discrimination of blind children.

Exceptional Children, 1972, 39, 120-124.

Studied the tactual discrimination performance of 36 blind 1st and 2nd graders. Metric figures from three levels of complexity (3 x 3, 4 x 4, 5 x 5) were combined factorially with three physical sizes (1, 2, 4) in a same-different pair-comparison discrimination task. Increasing levels of physical size and complexity had no effect on discrimination accuracy, but increasing levels of either physical size or complexity significantly increased task time. Overall accuracy of performance was low (62 percent correct discriminations) and it appeared that unsystematic and inappropriate hand and finger movements were responsible for the low level of performance.

Berla, E. P.

Behavioral strategies and problems in scanning and interpreting tactual displays.

The New Outlook for the Blind, 1972, 66, 277-286.

Interviews with 12 blind adults, all skilled users of tactual maps, provided information on a number of behavioral techniques and problems related to tactual displays of information, with the aim of ultimately increasing the efficiency of the methods used to teach children to use tactual maps. Subjects were asked to describe their strategies in locating symbols and following a track on a pseudo-map. The discussion includes description of various scanning techniques (one-hand, two-hand; horizontal and vertical; perimeter scan; bounded search; spoked wheel, etc.), as well as differences in hand and finger utilization, micro-motions, distances between hands, etc. Types of symbols, orientation, keys, and map "clutter" are also discussed. No attempt is made to quantify the information received from the subjects in the interviews; rather, the major commonalities and differences in the above-

mentioned areas are discussed. Basic concepts (with accompanying activities) felt by subjects to be necessary in teaching children to utilize tactual maps were: meaning of a symbol; lines, points, and areal symbols; discriminating bounded space; representations of the environment; and spatial relations and memory.

Berla, Edward P.

Strategies in scanning a tactual pseudomap.

Education of the Visually Handicapped, 1973, 5, 8-19.

Purpose: (a) to determine whether a brief period of instruction on scanning tactual displays increases efficiency; (b) to determine which search pattern is most effective. Method: 108 braillists from blind schools (36 grade 4-6, 36 grade 7-9, 36 grade 10-12) were presented with a tactual pseudomap with point and linear symbols. Three conditions of training (horizontal scan, vertical scan, no training) were combined factorially with two conditions of scanning (one hand, two hands)--training being an inter-subject's variable and scanning a within-subject's variable. Subjects with residual vision were blindfolded. Measures obtained of (a) total number of objects isolated correctly, (b) number of duplication errors, and (c) time taken. Results: Training blind students to scan in vertical columns resulted in the most accurate and consistent performances compared to a group trained to scan in horizontal rows, or an untrained control group. A high level of performance is obtained with one hand *and* two handed vertical scanning, with the latter being faster. Effects of training are moderate compared to the control group (10 percent increase in number of objects located, 200-300 percent decrease in variability with respect to duplication error). Control group significantly, but moderately, faster. In vertical scan, the use of a reference hand has no effect. In horizontal scan the reference hand leads to more symbols located, more errors of duplication made.

Best, B. D. A.

School braille--Suggestions for a new approach.

Teacher of the Blind, 1973, LXI, 113-116.

Recommendations for making braille easier. Best believes that the Standard English Braille Committee has been too clever and made the rules of braille too complicated--"It is vital to bring braille into popular use since it is the only medium offering the blind a chance to both read and write." School braille as Best visualizes it, consists of the alphabet and the five extra wordsigns "AND FOR OF THE WITH." The simpler upper wordsigns represented by letters of the alphabet are retained with the exception of k, x, and z. Now k represents "keep" instead of "knowledge," which is not phonetic. x and z are dropped altogether as they do not bear any resemblance to "it" and "as" respectively. Initial and final contractions are out--partly to help spelling and partly to do away with arguments about precedence of contractions. A list of abbreviations to be retained is included.

Bevans, J. E.

Development of a recreational music program at Perkins School for the Blind.

International Journal for the Education of the Blind, 1965, 14, 72-76.

A discussion of a music program in which the emphasis is on playing and experiencing music, rather than on learning *about* music in its technical sense. The program was devised to give a creative outlet to those students who haven't mastered the fundamentals of literary braille and therefore cannot receive braille musical instruction or participate in the school's regular musical activities, but who nevertheless should, it is felt, be offered the chance to enjoy and be successful in performing music. An outline is given of the programs in both the lower and upper schools. The lower school program involves extensive rhythm band work

and musical games (for the younger children); the older children develop more sophisticated rhythm techniques and also work with flutophones. Opportunities for performance are numerous and much use is made of tape recorders as teaching aids. The upper school works exclusively with recorders; all fingerings are taught verbally. Any learning of the technical aspects of music is incidental and thought to be of secondary importance. The discussion includes several ideas for adopting the Perkins program to the needs of a particular school.

Blackhurst, A. E., Marks, C. H., & Tisdall, W. J.

Relationship between mobility and divergent thinking in blind children.

Education of the Visually Handicapped, 1969, 1, 33-36.

In order to test the hypothesis that high mobility in blind children might have a positive relationship with divergent thinking, 76 blind children from day school programs and 76 blind children from residential schools were rated by their teachers on mobility in the classroom, in the school, and on the school grounds, using a 7-point scale. Sixteen subjects from 6 tests of divergent thinking were then administered to the subjects. Results from the day school group showed that 40 of 41 correlations were significant, but all were low (between 0.23 and 0.33); and the author suggests that although this may be statistically significant, it may not be psychologically meaningful. With this in mind, and since the highest significant correlation obtained was 0.33, it was concluded that any relationship which does exist between mobility and divergent thinking in day school children is at best a slight one.

For the residential school group, only 3 of 123 correlations were significantly different from zero; it was thus concluded that for this group no relationship between mobility and divergent thinking existed.

Blasch, B., Welsh, R. L., & Davidson, T.

Auditory maps: An orientation aid for visually handicapped persons.

The New Outlook for the Blind, 1973, 67, 145-157.

Auditory maps, recorded on cassette tapes, can be used to provide a visually handicapped person who is fully trained in the use of long-cane or dog-guide mobility skills with a verbal description to orient him to a specific travel area (district map) or step-by-step instructions to guide him to a particular objective (route map). It is suggested that the information included on such maps can best be prepared by an orientation and mobility specialist and that the content of the map can best be expressed using one or more of the following orientation reference systems: ego-centric, topo-centric, cartographic, and polar-centric. Suggestions are made for the use of specific mobility techniques and recordings of particular sound cues that might be encountered. Sample scripts for auditory district and route maps are included. The relative merits of auditory versus other types of maps are fully discussed, as are the wide variety of potential uses of such recorded travel aids.

Bledsoe, C. W.

For parents looking ahead to future mobility needs of their blind children.

International Journal for the Education of the Blind, 1963, 13, 13-16.

The author discusses the benefits of mobility training for the blind and feels that parents should be urged to put their blind children in the hands of competent instructors for such training. A brief history of the development of mobility instruction is given, along with some of the arguments advanced by critics of such instruction. The author suggests that one of the most important benefits which independent mobility gives to the blind is privacy--being able to travel without the inevitable accompaniment of another person--and it is

benefit, he feels, which outweighs the arguments against the need for mobility training.

Bohman, R. V., Bryan, W. H., and Tapp, K. L.

The auditory quiz board: An orientation and mobility game for visually handicapped schoolchildren.

The New Outlook for the Blind, 1972, 66, 371-373.

Describes a tool devised by and used at the Wisconsin School for the Visually Handicapped. It uses multiple choice questions, brailled or printed onto a wired form which is clipped to the surface of a battery-operated box designed to buzz when contact is made between a small probe and the correct answer to the question. The board has proved to be a good instrument for teaching cardinal directions and other basic environmental and geographical concepts preparatory to advanced orientation and mobility training.

Bongers & Doudlah.

Techniques for initiating visuo-motor behavior in visually impaired retarded children.

Education of the Visually Handicapped, IV(3), 1972.

Initially, these authors felt that the major developmental problem of the visually handicapped, multiply handicapped child was one of failing to extract and integrate sensory information from transactions with the environment--but such transactions in an institutional ward are routine and task specific and there are few opportunities for purposeful, multisensory learning experiences. Harnon had found that retarded visually handicapped children had a strong desire to look into a light source. A high intensity lamp was used to direct the child's attention in a dark room. Tasks learnt could be generalized by opening the door gradually till they were performing in a uniformly lit area. The lamp was also used as a manipulative object--the child was taught to switch it on and off. This was generalized to pushing the button on a water tap. Next he used a portable light table with a slanted work surface and an illuminated area containing two pieces of glass--one plain and one frosted. Designs to be copied were placed between the two pieces of glass and the child received a light reward as he performed tasks. Conclusion: (a) Visually handicapped retarded children can and must learn to attend to objects and tasks before they can be expected to develop visuomotor skills. (b) Restricted visual environments which direct the child's attention to the task are effective in initiating purposeful performance. (c) Light is a powerful reinforcer for these children. (d) The effectiveness of a technique can be evaluated by monitoring the appearance and spontaneous use of the skill by the child.

Bottrill, J. H.

Difference in curiosity levels of blind and sighted subjects.

Perceptual and Motor Skills, 1968, 26, 189-190.

In order to determine whether blind people are less curious than sighted and whether curiosity behavior is influenced by the degree and severity of blindness, a group of 28 blind subjects (16 students and 12 older non-students) and a group of 43 sighted subjects (33 students and 10 older non-students) were tested for locomotor curiosity and perceptual curiosity, using the pyramid maze and a modification of the Stimulus-variation Seeking Scale, respectively. Results of the perceptual curiosity test showed the sighted subjects to be significantly more curious than the blind subjects, but the locomotor test showed no such significant difference. No significant variation was found among blind subjects as to source or degree of blindness. It is suggested that these results indicate that while stimulation from the external environment may be the primary motivating factor in perceptual curiosity, the motivation toward locomotor stimulus-seeking behavior may be internal.

Bottrill, J. H.

Locomotor learning by the blind and sighted.

Perceptual and Motor Skills, 1968, 26, 282.

Thirty-three blind and 33 sighted subjects were tested on their ability to learn a raised, semi-linear U-finger maze, in order to determine whether blind people's continual need to locate themselves in their environment leads to the development of a "locating skill" which sighted people do not possess. Each subject's score was the total number of mistakes before he learned the maze, or before the end of the 20-minute test period, whichever was shorter. A t-test on the learning scores showed a significant difference between the blind and sighted. Only 34.4 percent of the blind and 39.2 percent of the sighted subjects managed to learn the maze within the allotted time. The author suggests that this, and the lack of group differences, might lead one to assume that blind people do not have a better cognitive idea of their surroundings than sighted people; however, the maze used in the experiment may provide insufficient cues, as it requires only simple arm and finger movements and thus limits the amount of kinesthetic sensations available, and these sensations may be of great importance to the blind in spatial location.

Bottrill, J. H.

Effectiveness of an adjustment course for those recently rendered blind.

Perceptual and Motor Skills, 1968, 26, 366.

In an attempt to evaluate an adjustment course for the newly-blind, 7 subjects and 2 control groups, one of 5 students blind since birth, and the other of 26 sighted students, were given orally the Neuroticism Scale Questionnaire (NSQ) and the Worchel Self-activity Inventory, at the beginning and again at the end of the 1-month course. Computation of t ratios revealed that the only significant ratio was on the NSQ for the adjustment class ($P < 0.01$) 5 of the 7 subjects of the experimental group refused to answer questions relating to sex on the Worchel Scale, and these items were omitted in all cases; the author suggests that as the self-concept appraisal was thus incomplete, this may have accounted for lack of significant differences. He suggests further that although the significant t ratio for the adjustment class may indicate that the test is an inappropriate measure of improvement, the smallness of the sample argues against too much reliance being placed on the results.

Bourgeault, S. E.

Self-imposed limitations in creative teaching.

International Journal for the Education of the Blind, 1963, 12, 115-116.

The author describes five symptoms of "professional rigidity" which he suggests limit the performance of potentially creative teachers of the visually handicapped: 1) strict adherence to certain presentation techniques; 2) prolonged use of "successful" techniques; 3) tendency to abandon too quickly techniques which have failed; 4) idealization of objectives, both for children and for the teachers themselves; 5) the stereotyping by teachers of the visually handicapped children they teach. It is suggested that a constant refusal to identify emotionally with specific techniques and procedures can lead to a more flexible approach to teaching and ultimately to a more creative solution to the problems of teaching methods.

Brambring, M.

Technical and practical utilization of electronic mobility aids for the blind.

American Foundation for the Blind, *Research Bulletin No. 25*, 1973, 257.

Three matched groups of 8 subjects each (blind, between 14 and 22 years old) were assigned to the Kay Sonic Aid training scheme, the Laser Cane training scheme and a control group with no training.

Training was 20 hours individualized instruction, locomotor proficiency being measured at three stages of learning. Conclusions: (a) locomotor proficiency is substantially influenced by training; (b) extent of training determined level of success attained in operating the aids; (c) no positive effects were demonstrated for the Kay Sonic Aid in these circumstances; (d) given comparable training, the Laser Cane led to objective and subjective improvement of performance; (e) however, these improvements appeared to depend on training effects rather than on the electronic system; (f) thus the correct procedure seems to lie in extensive mobility training to optimally exploit the natural capabilities of blind people; (g) further attempts to design technical aids should incorporate human factor principles, and take into account man's psychological characteristics.

Brothers, R. J.

Aural study systems for the visually handicapped: Effects of message length.

Education of the Visually Handicapped, 3(3), 65-70.

Assigned 6 braille readers and 4 large-type readers--blind high school students--to each of four groups. Subjects heard a 24-minute tape in 1, 2, 3, or 4 sections and were immediately tested after each section for information recall. Seventy-four hours later, subjects were again tested for recall. Recall was not significantly affected by message length but immediate recall was significantly more accurate than delayed recall ($p < 0.01$). Braille readers had significantly ($p < 0.05$) higher scores than the large-type readers on delayed recall. Limitations of the study are noted.

Brothers, R. J.

Arithmetic computation by the blind--A look at current achievement.

Education of the Visually Handicapped, 1972, 4, 1-7.

In order to determine: (1) the current achievement level of braille students (in U.S.A.) in arithmetic computation; (2) the difference, if any, between achievement scores of braille students on the SAT test of arithmetic computation for 1959 and 1970; and (3) possible relationships between SAT scores and type of computational device or strategy used by braille students, 269 blind students aged 6 to 20 were tested using the SAT (Scholastic Aptitude Test). Results indicated that the achievement levels of the 1970 group were consistently below those of 1959, although at the higher grade levels students attempted more responses in 1970 than in 1959. A relationship was found between achievement and type of device or strategy used in computation for the 1970 8th-grade group only, where 43 percent of the students using an abacus achieved at or above the expected grade level of 8.2. Educational implications are discussed.

Brown, G. D., & Jessen, W. E.

Preliminary performance test battery of orientation, mobility, and living skills.

American Foundation for the Blind, *Research Bulletin No. 24*, 1972, 1-20.

Sixteen blind children, median age 13, attended a three-week workshop of daily classes in orientation, mobility, and living skills. Twenty-one preliminary performance tests were developed to evaluate the workshop. Students achieved significant increments in performance on four of the living skills tests and on one of the orientation mobility tests. Staff members were in close agreement when ranking students for proficiency and improvement in orientation and living skills. Comparison with performance measures indicated that staff gave almost equal weight to orientation and mobility and to living skills when

ranking students for proficiency. There was little relationship between subjective ranks for improvement and distributions of differences obtained from pre- and post-test scores. The feasibility of developing a performance battery of orientation, mobility and living skills was demonstrated. A preliminary manual for the OMTB is presented in an appendix.

Brown, J. D.

Storytelling and the blind child.

The New Outlook for the Blind, 1972, 66, 356-360.

Obtained 72 questionnaire responses from 160 mailed to librarians, teachers and specialists. Results unequivocally indicate that storytelling is an effective tool when properly utilized for aiding children's mental development. It is noted that story tellers must realize the importance of their voices and differences in reactions of blind children as against sighted ones. It is suggested that story tellers (a) know their audiences beforehand in regard to average age and attention span of the group, and home and school interests; (b) develop themes; (c) select suitable books; (d) read material several times aloud and commit to memory; (e) make use of inflectionary and modulatory voice and tones; and (f) encourage audience participation. A list of 37 stories enjoyed by blind children is included.

Bruce, R.

Using the overhead projector with visually impaired students.

Education of the Visually Handicapped, 1973, 5, 43-45.

For six years the overhead projector has been used for high school maths at the Virginia Deaf-Blind School. The classroom is darkened to cut out the glare which is troublesome to partially sighted children. Students move their desks to places suitable to their needs--in some cases between the projector and screen. If light reflected from the screen is not sufficient, they are provided with desk lights. The lens is focused for the majority of students, then refocused for those who require it. Those sitting near the screen can only see the bottom half clearly so the lens housing is tilted to focus the whole image on the bottom half of the screen. Students with very low vision stand next to the projector and look directly at the film (or at the wire, geometrical objects which can be projected onto the screen). Blunt felt tips are used to make the lines thicker and easier to see. The Overhead Projector has been found to focus the attention of the students and is flexible and adaptable to the needs of the teacher and pupil. There is a range of instruments which can be used and the simultaneous use of auditory and visual modes improves retention of material taught.

Calek, O.

Distressful life situations and the emotional strain felt by subjects with severe visual defects.

American Foundation for the Blind, *Research Bulletin No. 25*, 1973, 59-69.

Eleven subjects between 18 and 20 years old, all totally blind, psychologically naive, prospective music teachers. Several problems relating to the inner life of the visually impaired were studied. An attempt was made to describe the emotional strain in the life of the severely visually handicapped and to discover whether it was as stressful as the objective visual deficiency. The causes of emotional strain were sought among the stresses, frustrations and conflicts of their life situations. Their sensitivity to the so-called higher or social needs was analyzed and compared with frustration levels at the level of lower, biological needs. Investigation was made into the character of modes of coping with stressful life situations. Special attention was paid to defense reactions showing clearly indications of maladaptation. The causes of physical appearance and the ways they were acquired were also investigated.

Lastly, the role of the life history of the visually impaired was considered, including the influence of personality traits on modes of coping with stress situations and on the specificity of behavior.

Carolan, R.

Sensory stimulation in the nursing home.

The New Outlook for the Blind, 1973, 67, 126-130.

To continue functioning adaptively, the individual needs constantly varying forms of sensory stimulation. Since such stimulation is often neglected in the nursing home environment, producing particularly devastating psychological effects in the sensorily impaired person, specific suggestions are provided for improving this situation. Orientation and mobility specialists can be invaluable catalysts in providing the skills and motivation necessary for enriching such an environment. Specialists and regular staff can, by analyzing the person's entire daily routine, provide many opportunities for additional sensory stimulation.

Carolan, R.

Sensory stimulation and the blind infant.

The New Outlook for the Blind, 1973, 67, 119-126.

To develop properly, it is necessary for the infant, and particularly the infant who is blind, to be provided with a rich environment of sensory stimulation. When such stimulation is absent, as evidenced by the findings of researchers in sensory deprivation, a variety of undesirable behaviors can result. Parents can be helped in a variety of ways to provide their child with adequate stimulation. The concept of an infant curriculum, as developed by Barsch, is suggested as a particularly useful means of insuring that appropriate kinds and amounts of sensory stimulation are provided at each developmental stage.

Chase, J. B., & Rapaport, I. N.

A verbal adaptation of the draw-a-person techniques for use with blind subjects: A preliminary report.

International Journal for the Education of the Blind, 1968, 18(4).

A verbal adaptation of the Draw-A-Person Test (VDAP) was administered to 75 subjects. An equal number of sighted subjects took the DAP and VDAP and three judges later blind-matched a random sample of ten of these drawings with their verbal counterparts. Correct matchings were found to be significant beyond the 0.001 level, suggesting a congruence of clinical interpretation of both instruments. Further validation research is anticipated.

Cicenia, E. F., Belton, J. A., Myers, J. J., & Mundy, G.

The blind child with multiple handicaps: A challenge. Part II.

International Journal for the Education of the Blind, 1965, 14, 105-112.

Johnstone Training and Research Center has developed a continuum of therapeutic educational experiences for multihandicapped children.

Failure of the educational program was recognized in the beginning due to the emphasis on the "three R's." Likewise, an emphasis on self-care and activities of daily living was unsuccessful because the emotional needs such as security promotion, acceptance promotion, fear alleviation, and human interactions were necessary before learning as such could begin. An educational sequence of management skills, motor experiences, selected academics and group integration has been developed.

Clegg, G.

A study of the tactual discrimination test for measuring tactual ability of the visually handicapped.

American Foundation for the Blind, *Research Bulletin No. 25*, 1973, 259.

Hypothesized that level of performance on TDT would be positively related to ability to discriminate braille characters. Tested 52 legally blind participants who had completed a course in braille reading. They had to sort 56 pieces of sand paper of various sized grits (14 each of extra fine, fine, coarse, extra coarse) into a box. This box was sectioned into 4 small bins, one large (closest to the subject), the box being waist high at an angle of 30 degrees. A sight occluder was used. Two measures--time of sorting and number of correct responses were found to be significantly correlated with braille rankings ($p < 0.01$).

Coffey, J. L.

Programmed instruction for the blind.

International Journal for the Education of the Blind, 1963, 13, 38-44.

A series of objectives to explore the possibilities of programmed instruction for use of blind students is outlined by Battelle Memorial Institute. Evaluation of an experimental program led to these conclusions: (a) programed instruction is feasible and as desirable as for sighted students; (b) programs written specifically for the blind should be tested; (c) verbal responses were better for junior high students, but braille responses for senior high students are effective; and (d) mode of presentation (aural or braille) is not significant.

Condricek, R., Meehan, F., & Love, J.

A new braille medium.

American Foundation for the Blind, *Research Bulletin No. 25*, 1973, 69-94.

A report on the development of a new system converting coded ink-print into braille. There are three components: (a) The ink-print medium --composed by computer, typeset by photocompositer, printed by photo offset. A standard 3 x 2 braille cell is coded into a 1 x 6 array. Each dot is contained in a square of side 1/100". To allow separation of lines, the top half of the square is white. Presence of a dot is represented by black bottom left hand quarter, white bottom right hand quarter. Conversely for absence of dot (i.e. 25 percent of the square is always black--this facilitates tracking). A standard sheet of coded ink-print can contain more information than a standard volume of braille --an enormous reduction in bulk and inconvenience. (b) The optical reading device. This reads one line at a time, collects groups of 6 dots, holds a number of them and feeds them into a transducer. This device will change line automatically and read in either direction. It also provides the number of the media line being read to the transducer. (c) The transducer. This converts the electrical impulses generated by the optical reader into a form acceptable to the blind reader--so far attention has been concentrated on braille. Bumps are activated to simulate embossed braille and pass beneath the reader's fingers. A string of characters is continuously available to the reader who can retrace misunderstood words by backing up.

Conner, G. B.

Blindness 1964.

Washington, D.C.: American Association of Workers for the Blind, Inc., 1964. 175 pp.

The title of every government sponsored research project relating to blindness is listed along with a short resume of the study and the

principal researcher as well as publication sources.

A variety of definitions from numerous countries provides strong support for an examination of defining procedures and highlights the pressing need for a more communicative vocabulary in regard to visual handicaps. A realistic discussion of the newer concepts in mobility precipitated by technological advances places a new perspective on travel techniques and devices. Variables other than the objective analysis of the amount of residual vision must be considered in mobility training of persons with partial vision.

Coveny, T.

A new test for the visually handicapped: Preliminary analysis of the reliability and validity of the Perkins-Binet.

Education of the Visually Handicapped, 1972, 4, 97-101.

Subjects: 55 students (grades 3-6): 30 braille readers 8-9 to 14-9 age range) and 25 print readers (age range 8-0 to 16-5), all at blind school. The Perkins-Binet has two forms--form N (no useable vision) and form U (useable vision). These were administered to the appropriate groups together with the W.I.S.C. (half had the W.I.S.C. first and half the Perkins-Binet first in each group). The reliability of the test was tested with a split half reliability technique. Results: Both forms of the Perkins-Binet showed a high degree of internal consistency and the highly significant correlations between the Perkins-Binet and the W.I.S.C. show that both scales are measuring, to some extent, the same abilities. But the Perkins-Binet and W.I.S.C. scores are not interchangeable, standard deviations on the Perkins-Binet being larger than with the W.I.S.C. Coveny recommends reporting Perkins-Binet scores as mental age rather than I.Q. The Perkins-Binet appears to be a valuable clinical instrument, giving information about degree and quality of residual vision as well as tactual perception. More research is needed, though, to determine its value as a predictor of academic achievement. Until such data is available, the Perkins-Binet should be a very useful resource for the clinician, providing pertinent educational data not accessible through the use of verbal instruments such as W.I.S.C. and Haynes-Binet.

Craig, E. M.

Role of mental imagery in free recall of deaf, blind, and normal subjects.

Journal of Experimental Psychology, 1973, 97, 249-253.

Tested A. Pavio's dual coding hypothesis (see Psychological Abstracts, Vol. 43: 10753) in an experiment with 40 undergraduates, 40 deaf adolescents and 40 blind adolescents. It was hypothesized that the deaf store information almost exclusively in a non-verbal code, while the blind primarily use an auditory-motor code (verbal). Differential retention effects were therefore expected for the two groups for words which seem to differ in the ease with which they elicit non-verbal imagery. All the groups recalled high-imagery words better than low-imagery words; this was predicted from the normal and deaf but not for the blind. A significant Group X imagery level interaction was found for the normal-blind comparison, but not for the normal-deaf comparison. Serial position effects support the dual coding hypothesis.

Cull, J. G., & Hardy, R. E.

Language meaning (gender shaping) among blind and sighted students.

Journal of Psychology, 1973, 83, 333-334.

Examined whether substantially different word meanings exist within the language systems of blind and sighted students. Twenty-two totally blind and 64 sighted high school students were randomly selected and administered the Gender Association Survey. Blind subjects showed significant differences ($p < 0.05$) from

their sighted counterparts in assigning gender to 17 out of 50 commonly used words. Language seems to help condition perception and people who are deprived of vision seem to have different interpretations concerning the meaning of words in the language.

Curtis, J. F., & Winer, D. M.

A comparison of the efficacy of two methods of mobility training for the blind, using blindfolded sighted subjects.

American Foundation for the Blind, *Research Bulletin No. 22*, 1970, 119-129.

Two methods of mobility training currently being used with the blind, tactile maps and binaural recordings, were evaluated by measuring the travel performance of 7 groups of blindfolded sighted Ss following training with various combinations of training methods. The Ss' travel performance was measured on a one-block course in a small town. Each S made 2 round trips on this course. A balanced design was used, with some groups receiving no training, some receiving only one type, and some receiving both types, either between the 2 trips, or prior to them. The results indicate that there is no statistically significant difference in travel time or path on the sidewalk among any of the groups.

Dauterman, W.

Manual for the Stanford multi-modality test.

New York: American Foundation for the Blind, 1972.

Details the standardization studies for the Stanford multi-modality test which measures the blind person's ability to use imagery in solving mobility and other daily living problems. Methods for scoring and interpreting are presented. Indexes on testing the deaf-blind and on the blind examiner are included.

Davidson, P. W.

Haptic judgments of curvature by blind and sighted humans.

Journal of Experimental Psychology, 1972, 93, 43.

Three experiments investigated the relationship between active handling and veridical haptic curvature perception. Experiment 1 showed that blind subjects made more objective judgments of curves than did sighted subjects. Videotape recordings of exploratory scanning during the judgments revealed that the blind subjects used a scanning technique allowing more global apprehension of the stimulus parts. In experiment 2 sighted subjects' judgments became more objective when they were restricted to using the scanning technique characteristic of the blind. Experiment 3 suggested that sighted subjects' errors in experiment 1 probably stemmed from using movements that obscure stimulus curvature. It was concluded that the blind's scanning technique (a) focused attention to an informative stimulus feature, and (b) provided a way to pattern the ends-to-middle relationship that specifies curvature. Implications for a theory of the role of exploratory activity in perception were discussed.

Davidson, P. W.

The role of exploratory behavior in haptic perception: Some issues, data, and hypotheses.

American Foundation for the Blind, *Research Bulletin No. 24*, 1972, 21-27.

Reviews recent studies of tactile-kinesthetic perception. The accuracy of such perception is discussed in terms of focus-of-attention, scanning materials, autogenetic development, and experience factors. It is felt that understanding of these interrelationships may result in improved information gathering and coding activities of the blind.

Davis, P., Asarkof, J., & Tallman, C. B.

A closed-circuit television system as a reading aid for visually handicapped persons.

The New Outlook for the Blind, 1973, 67, 97-102.

Although most visually handicapped patients can be adequately rehabilitated visually through the prescription of low vision optical aids, some who have very poor vision and who need to do a great deal of reading may be helped through the prescription of a closed-circuit television reading system. It was found that 6 of 17 patients tested with such a system could benefit from it. The system used includes a push-button operated scanning device for shifting the image on the page.

Dickey, T. W., & Vieceli, L.

A survey of the vocational placement of visually handicapped persons and their degree of vision.

The New Outlook for the Blind, 1972, 66, 38-42.

In order to determine the occupational areas in which visually handicapped clients are being placed, the range of visual acuity among those being placed, and the kinds of questions employers were asking during job development interviews, 225 questionnaires were mailed to graduates of the Placement Counselor Training Program of Southern Illinois University. The 77 usable returned questionnaires placed a total of 1733 clients in 18 specified occupational areas and in the category "other" for the period 1 July 68 - 15 April 70. The occupational area, "industrial," showed the largest numbers of placements (600), with self-employment second (191), and clerical third (160). With respect to vision, 43.4 percent of those placed had visual acuity of 20/200 or better, 42.9 percent had 20/200 or less but were not totally blind, and 13.7 percent were totally blind. Among the legally blind persons, 24.3 percent were totally blind, a figure which closely approximates the 25.5 percent of totally blind persons in the legally blind population who are 20 to 60 years of age.

Dolan, W.

The first ten months of the rubella living unit.

The New Outlook for the Blind, 1972, 66, 9-14.

Describes operation of a Rubella Living Unit established to halt regression and teach basic self help skills to a group of pre-school deaf, blind, mentally retarded children, mostly confined to beds in a residential school. Originally 6, then 10, children with 9 staff members working 12 hours, 7 days a week formed this unit. Improvement of the child's life style, helping him reach his maximum potential and determining the most effective teaching techniques with this type of child were the objectives. Means for achieving them were instructing the children in daily living skills, enlarging experiences by field trip and improving interactions with peers and staff and evaluating the educational potential. Six case histories are presented, emphasizing that such children are able to learn if someone believes in the child's potential and gives enough of himself to the learning situation.

Drever, J.

Early learning and the perception of space.

American Journal of Psychology, 1955, 68, 605-614.

Subjects: 2 groups of 37, matched for age, sex and intelligence--one blind, one sighted. Average age--14-11, 15-3, respectively. Average intelligence 111.7, 116.1 respectively. The blind group was subdivided into 2 matched groups--early blind (before age 4), and late blind (after age 4 but at least 2 years before the experiment). Sighted subjects were blindfolded for the 4 tests. (1) A Figure Recognition Test. Subject given 2 parts of a figure (circle, semi-circle, etc.) to handle separately but not to put together. Subsequently he had to decide which of 4 figures would have been made from the parts he had. In this test, the sighted were slightly superior to the late blind, who were far superior to the early blind. (2) An Orientation

Test. This involved a 10 x 10 peg-board with 1" between holes, pegs sticking out 1/4". Subjects had to feel a configuration of pegs, hold on to the last one while the board was rotated through 180° and then, after the pegs had all been removed, replace them in the holes they occupied before rotation. In this test the late blind were considerably superior--with the early blind and sighted very close to one another. (3) A Short Classification Test. Subjects had to choose the odd one out of three configurations in the peg-board--two of which were similar in shape but had different numbers of pegs, two of which had equal numbers of pegs, i.e., .:./.˙./. ⁝ Here, the blind classified by shape, the sighted by number. The sighted when unblindfolded, classified by shape like the blind. (4) A Test of the Tactile-Kinesthetic Perception of Straightness. This showed that the blind are superior to the sighted in both objectivity and consistency. In none of the tests was age of onset after 4 significant, nor age, nor intelligence. The tests seem to indicate that some skills are built up early, and later learning has little effect.

Duche, D. J., Rausch de Traunenberg, N., & Bouras, A.

Value of psychological techniques in the examination for detection of visual disturbances in the 3-6 year old child.

Psychological Abstracts, 1973, 49(4), No. 7129.

Studied 84 3-6 year olds to determine factors which might help in validating ophthalmological screening examinations. Results of the Stanford-Binet Intelligence Scale Form L, and of the Columbia Mental Maturity Scale show that two types of children present difficulties which might invalidate ophthalmological examinations--those with slightly deficient I.Q.s, or those with normal intelligence but severely inhibited personalities. It is concluded that general psychological maturity and level of perceptual-motor integration determine the capacity to adequately respond to presentation of the test-types. Errors of estimation due to factors other than visual function appeared in 16 percent of the subjects.

Dumas, G.

Mimicry of the blind.

. . . *And there was light*, 1932, 2, 30-33 (in French).

Psychological Abstracts, 1933, 7, Item 2205.

"To find out whether in mimicry we are imitating ourselves, by means of consciousness of our spontaneous expression through our muscular and cutaneous sensibility, or are imitating someone known to us visually, some 30 observations have been made on people born totally blind. The results indicate that mimicry is based on visual observation although possibly the blind might be taught a certain amount of mimicry through tactual observations."

Duran, P., & Tufenkjian, S.

The measurement of length by congenitally blind children and a quasiformal approach for spatial concepts.

American Foundation for the Blind, *Research Bulletin No. 22*, 1970, 47-70.

The major task of this study was an analysis and description of the use of the haptic sense as it bears on the blind child's perception of length. Congenitally blind children were chosen as Ss in order to isolate those perceptions derived through tactile learning. This paper presents a quasiformal approach and point of view for investigating spatial concepts and describes an experiment inculcating this point of view. In the quasiformal approach the behavior of an organism is differentiated into four parts: input, memory, logic, and display. It was found that the major classes of methods for measurement of length by congenitally blind children are: juxtaposition and noncoincidence of endpoints, body part as measuring instrument, kinesthesis, time duration, and physical principles. The principal conclusions were:

(1) The physical size of the objects will determine the technique used for the measurement; and (2) as the physical length of the object increases, the corresponding difference threshold increases independently of the technique used.

Elonen, A., & Cain, A. C.

Diagnostic evaluation and treatment of deviant blind children.

American Journal of Orthopsychiatry, 1964, 34, 625-633.

Visually handicapped children with varying types and degrees of developmental problems are often misdiagnoses. Even if diagnosed correctly, they continue to bewilder parents, psychologists, medical experts, and educators because of the lack of treatment plans, programs, or centers.

A therapeutic approach in a psychiatric clinic revealed notable progress in behavioral development with eventual entrance into local and residential educational programs for many children. The study verified that pessimistic diagnoses and prognoses are not acceptable without (a) prolonged study and therapeutic care; (b) cooperative communication and planning of many disciplines is indicated; and (c) older concepts regarding the influence of visual handicap on personality development deserve re-examination.

Espinda, S. D.

Color vision deficiency--A learning disability?

Journal of Learning Disabilities, 1973, 6, 163-166.

Hypothesized that color vision deficiency would be associated with impaired learning, inappropriate classroom behavior and a higher frequency of referrals to programs for the educationally handicapped. Diagnostic color vision screening was conducted for 83 males in 11 classrooms for the elementary level educationally handicapped and for 139 males in 11 regular 3rd and 4th grade classrooms. Deficient color vision was found in 13.25 percent of educationally handicapped and 5.05 percent of regular class ($p < 0.05$). Hypothesis confirmed.

Evans, R., & Simpkins, K.

Computer assisted instruction for the blind.

Education of the Visually Handicapped, 1972, 4, 83-85.

Fourth, 5th, and 6th graders use computers in math lessons at a school in Philadelphia. The program has 6 grades and the child goes through at his own rate, reviewing when necessary. Each child is first taught to use the keyboard on a thermoform reproduction. When a child answers incorrectly, the computer types "wrong--try again." After 3 tries the answer is typed in and the student types it again for reinforcement. He is told at the end how many correct responses he's made. If he has only made 2 errors, he goes on, otherwise he repeats the lesson. The braille characters are printed out on thin paper by means of a braille adaptor. It is in grade 1 braille which is difficult for students accustomed to grade 2. Also no number signs precede numbers which is confusing. Thirdly the multiplication and division on the abacus is done from left to right but the computer must have input and output right to left. But all these difficulties have been overcome with time and patience and the children are all very enthusiastic.

Flanigan, P.

Automated training and braille reading.

The New Outlook for the Blind, 1966, 60, 141-146.

Braille reading of 15 experimental and 15 control subjects was compared as a function of training, the experimental subjects using an automated self-learning device,*

*This introduces braille on a tape moving from right to left under the subject's fingers.

and control subjects reading traditional braille. Analyses of the data indicated (1) performance of experimental subjects was significantly superior to that of control subjects on certain variables (retracings, vertical movements) involved in the traditional braille reading process; (2) following a non-instructional period of 3 months, the experimental gains remained constant; (3) nonsignificant treatment effects were noted on comprehension and reading achievement level as a function of the method of reading; and (4) the appropriateness of sequenced grade-level reading materials for reading instruction was pointed out. Suggestions for future research were given.

Fonda, G.

Management of the patient with subnormal vision.

St. Louis: C. V. Mosby Company, 1965. 160 pp.

Not only does this book provide comprehensive coverage of clinical procedures for examination of low vision patients, it also includes a readable explanation of magnifiers, telescopic systems, and visual aids in general. Four chapters are devoted to information which is invaluable to teachers of visually handicapped children. Covered are such topics as (a) classifications of degrees of vision, type size, and related magnification, (b) training and instruction in the use of optical aids, and (c) a valuable question and answer section which should clarify many misconceptions.

Fraiberg, S.

Separation crisis in 2 blind children.

Psychoanalytic Study of the Child, 1971, 26, 355-371.

Describes the factors which aggravate the separation crisis for the blind child and his mother. Lack of vision limits the perceptual field within which the child is aware of his mother's presence. Evocative memory develops more slowly in the blind as do the motor patterns for fighting and the ability to discharge anger. A 14 month old not yet creeping, after separation from his mother for 3 days developed pathological screaming and regressed. His mother, herself somewhat unstable, was helpless. When rage was recognized as one component of the screams, and the child was encouraged to use banging and pounding toys, screaming stopped and normal development resumed. For a 19 month old, all factors were more favorable. He was precocious, especially in language development, mobile, and could follow his mother about. Substitute care during the period of separation was superior to the previous case. His mother was more skillful in translating his messages and in making the appropriate response. No regression or unfavorable symptoms developed.

Franks, F. L., & Baird, R. M.

Geographical concepts and the visually handicapped.

Exceptional Children, 1971, 38, 321-324.

Reports the third in a series of studies exploring geographical concept attainment in visually handicapped students as a basis for improving ability to interpret embossed maps. Studies 1 and 2 are briefly summarized as background. In study 3, 24 braille and 24 large-print readers were tested on three-dimensional raised surface models (land forms), which were tactually and chromatically coded. Results indicate that the landforms provided highly discriminable illustrations of 40 basic geographical terms and the codes furnished effective cues. It is concluded that the materials should greatly facilitate both instruction and evaluation of geographical concept attainment.

Friedman, J., & Pasnak, R.

Attainment of classification and seriation concepts by blind and sighted children.

Education of the Visually Handicapped, 1973, 5, 55-62.

Subjects: sighted - 10 first graders (age 6), 10 third graders (age 8), 10 sixth graders (age 11); blind - 21 grades 1-6 (ages 6-14). Sighted subjects were blindfolded in non-verbal tests. Classification: discovery of class, classification of form, size, texture, orientation. Seriation: size, length, weight, seriation of recognizable forms. Verbal: analogues of discovery of class and seriation of recognizable forms, transitivity. Three sessions, in this order, of testing were carried out with each child, individual testing. Results: in general, sighted perform more adequately than blind children. (1) Conceptual abilities of classification and seriation continue to develop in all children at least to age 11. (2) Perceptual factors intrude so much that they may not be good indices of conceptual ability. Changing perceptual qualities (objects used) a little, often changed error scores considerably--apparently because the children's mastery of the concepts was incomplete. (3) Blind and sighted children are approximately equal in classification and seriation at 8 years of age, but afterwards the blind tend to fall behind, especially on verbal tasks. (4) Lack of vision impairs performance on visual tasks as well as manipulative tasks when these tasks involve conceptual ability. Conclusion: if acceleration of conceptual ability can be achieved by training children on Piagetian indices of conceptual ability, the blind child will profit most.

Genensky, S.

A functional classification of the visually impaired to replace the legal definition of blindness.

Teacher of the Blind, 1973, LXI, 82-91.

Rather than a system which classifies a man as blind on the basis of a specified visual acuity or visual field, we need a system which also accounts for the functional capability of an individual. Genensky proposes four categories classifying on two criteria: (a) whether or not a person can maneuver safely in an unfamiliar environment without guide dog, sighted guide, etc. (b) whether or not they can read ink print, and write like a sighted person. Genensky feels it unfortunate that the legally blind are treated as a visually homogeneous population--this creates functionally blind people who could have been encouraged to be functionally sighted. It also tends to involve stereotyping of jobs, hobbies, lessons thought suitable for the blind. There is no necessity for any but the functionally blind to be taught to read braille. This group is becoming smaller as new aids are discovered (e.g., one "Light Perception" person can now read ink-print-x-4 on the C.C.T.V. aid). Those who can be taught to read and write ink-print with whatever aid is required should be taught to--it is vital to the emotional and mental health of the visually impaired that they become as independent as possible.

Gescheider, G. A., Wright, J. H., & Evans, M. B.

Reaction time in the detection of vibrotactile signals.

Journal of Experimental Psychology, 1968, 77, 501-504.

Three subjects made judgments of the presence or absence of a burst of 200-cps vibration on the index fingertip. The probability of subjects reporting the presence of a signal was found to be influenced by the probability of signal occurrence and signal intensity. A family of ROC curves describing the effects of signal probability on response probability for each signal intensity level was interpreted as support of the applicability of signal detection theory to the judgment of cutaneous stimuli. Manipulation of signal intensity and signal probability also led to changes in subjects' reaction time for saying "yes" and for saying "no" when the signal was present and when it was absent, supporting the conclusion that subjects' decision time was longer the closer on the sensation continuum a particular sensory observation was to his criterion.

Goldblatt, M., & Steisel, I. M.

Behaviour modification with multi-handicapped blind children.

Proceedings of the 81st Annual Convention of the American Psychological Association, Montreal, Canada, Vol. 8, pp. 809-810, 1973.

Notes that although a large and growing literature exists on the use of behaviour modification techniques with children who manifest various aberrant behaviours, reports of work with blind and multi-handicapped children are rare. The behavioural analysis treatment plan, and results of programs designed to modify the behaviour of 3 children who attend a day school for the blind are presented. The pinpointed behaviours were assaultive acting out, rumination during and following meals, and sleeping during school time. The targeted, objectionable behaviours diminished, pro-social behaviour was acquired and the teachers were able to make more positive, educational approaches to the children.

Goldish, L. H.

The severely visually impaired population as a market for sensory aids and services: Part one.

The New Outlook for the Blind, 1972, 66, 183-190.

In this, the first part of a review of the question of sensory aids, the author presents the findings of a survey of the potential market for sensory devices among the visually handicapped in the U.S. The article includes discussions on the definitions of blindness, and the factors to be considered when deciding upon a particular aid or device, as well as a large number of statistics describing the number, activities and characteristics of the visually handicapped in the U.S.

Graham, M. D.

Wanted: A readiness test for mobility training.

The New Outlook for the Blind, 1965, 59, 157-161.

The lack of an entrance exam prior to admittance for mobility training is a critical factor; without such a measure one has no indication of the degree of predicted success. Existing data on 100 blind adults not associated with agencies for the blind were explored. Those in the high activity group gave evidence of certain specific characteristics.

Regardless of the age of the visually handicapped person, multiple factors appear to comprise the mobility patterns; therefore, successful attack on the problems of mobility for children and adults is dependent on the development of, experimentation with, and standardization of rational procedures for selection of trainees and evaluation of performance.

Guldager, L.

Using video tape in the education of deaf-blind children.

The New Outlook for the Blind, 1972, 66, 178-182.

The use of video-tape at the Perkins School in the education of the deaf-blind is discussed. The author sees the main advantages of this method to lie in the areas of teacher self-evaluation, teacher training (including the development of a tape library of the various behaviors and syndromes of deaf-blind children and the techniques used in their education), and the education of the deaf-blind children themselves, assuming that the children have sufficient vision to see the monitor. In this latter area the author mentions video-taping outings to facilitate later classroom discussion, using video-tape to present new concepts and give children the chance to experience things normally unavilable in the classroom, giving practice in speech-reading by taping 5-minute talks, and developing video-taped programmed

instruction techniques. It is anticipated that in the future the video tape will also be utilized in the auditory training of deaf-blind children.

Halpin, G., Halpin G., & Tillman, M.

Relationships between creative thinking, intelligence and teacher-rated characteristics of blind children.

Education of the Visually Handicapped, 1973, 5, 33-38.

Subjects--63 blind children from residential blind schools, 20 from day blind schools. Purpose--to test the relationship between (a) creative thinking and teacher ratings on mobility, adjustment to blindness, social acceptance, dependence, conformity, rigidity, curiosity, academic achievement, (b) I.Q. (WISC; Hayes-Binet) and teacher ratings, (c) I.Q. and creative thinking. (Creative thinking being made up of fluency, flexibility and originality and measured by the Torrance Tests.) Results--(a) Only curiosity was related to creative thinking on all three dimensions. Rigidity and academic achievement correlated with flexibility. (b) Only curiosity is correlated significantly with I.Q. (c) I.Q. is only correlated with flexibility. Conclusion--the blind child scoring high on verbal flexibility is more likely to be rated by teachers as non-rigid, adaptable, acceptable to change, likely to try new ways of doing things and also to do good school work. A child scoring high on all three variables in creative thinking and with a high I.Q. is likely to be rated high on curiosity, desire to know more about self and environment, and to seek new experiences.

Hapeman, L. H.

Developmental concepts of blind children between the ages of 3 and 6 as they relate to orientation and mobility.

International Journal for the Education of the Blind, 1967, 17, 41-48.

The author describes the various concepts necessary to the development of mobility and orientation in the blind child, with the aim of giving parents an awareness of these concepts in order that they might provide opportunities for the blind child to experience them. The concepts are divided into 3 groups: (1) concepts needed for understanding the true nature of the environment (including body image, nature of objects, nature of terrain, etc.); (2) concepts needed for achieving and maintaining orientation (including path of moving objects, directions, sound localization, etc.); (3) concepts needed for efficient mobility (including distance and time, turning, detouring, etc.). The author stresses that it is only through concrete learning experiences that a blind child will develop these important concepts.

Hare, B. A., Hammill, D. D., & Crandell, J. M.

Auditory discrimination ability of visually limited children.

The New Outlook for the Blind, 1970, 64, 287-292.

The purpose of this study was to investigate the relationship between sound discrimination ability and blindness, degree of visual acuity, tactile-kinesthetic ability, chronological age, and mental age. Eighty-five visually limited and 77 sighted children were given Form A of the Irwin Sound Discrimination Test, and a tactile-kinesthetic discrimination test (Crandell, Hammill, Witowski, and Barkovitch, 1968). Mental age was estimated by using either the Hayes-Binet Intelligence Scale, the Verbal Scale of the WISC, or the Slossen Intelligence Test. Analysis of the data yielded the following results: (1) There was no significant difference in sound discrimination

ability between visually handicapped and sighted Ss with similar mental and chronological ages. (2) No significant relationship was found between sound discrimination ability and either degree of sight or tactile-kinesthetic skills. (3) A significant relationship for both groups was found between sound discrimination ability and mental age (p less than 0.01), and for the visually handicapped Ss between sound discrimination ability and chronological age (p less than 0.01).

Harley, R. K., & Rawls, R. F.

Comparison of several approaches for teaching braille reading to blind children.

American Foundation for the Blind, *Research Bulletin No. 23*, 1971, 63-85.

In order to develop and field-test materials to be used in a 2-year study to compare 6 approaches in teaching braille reading to blind children, materials in 2 braille media--grade 1 and phonemic--were devised and tested, along with the traditional grade 2 system, in 2 basal readers, using contrasting approaches, analytic and synthetic. The 39 Ss, aged 5-10 years, were located in 6 classes in 6 residential schools for the blind. Teachers received special preparation prior to the start of the school program. Ss were introduced to the materials following a readiness program, and a daily progress report was kept by each teacher; teacher reactions were later used in the evaluation of each approach. Results of the Slosson Oral Reading Test and the Gilmore Oral Reading Test administered at the end of the academic year indicated that phonemic braille could be used successfully with these beginning braille readers. The analytic approach appeared to function more effectively for the phonemic materials than the synthetic approach. The effectiveness of the grade 1 approaches was not adequately measured. A study of longer duration with more Ss and more adequate materials is necessary to make generalizations concerning the efficacy of approaches in braille reading.

Harley, R. S., Pollen, J., & Long, S.

A study of the reliability and validity of the visual efficiency scale with pre-school children.

Education of the Visually Handicapped, 1973, 5, 38-42.

Subjects: 104 nursery and kindergarten children, the former being in the 4 year age group, the latter 5-6-1/2 years of age. Purpose: to test the Barraga (1970) Visual Efficiency Scale. Method: the Barraga Scale was administered individually to all the children, some of the younger ones having two short sittings. Results: the scale was found to have both content validity and acceptable internal consistency. Item analysis indicated that many of the items did not discriminate sufficiently between high and low scorers (the top 27 percent and the bottom 27 percent). Results also indicated that some items are inappropriately placed according to efficiency rating and some areas of the profile are not represented by discriminating items, e.g. object contour, light/dark intensity, image constancy of outlines, pattern details and objects.

Havill, S. J.

The sociometric status of visually handicapped students in public school classes.

American Foundation for the Blind, *Research Bulletin No. 20*, 1970, 57-91.

The purpose of this study was to examine the peer-acceptance level of visually handicapped children integrated in regular classes. Sixty-three visually handicapped children from grades 4 through 12 with no other handicap formed the experimental group. Each visually handicapped subject was matched with a sighted classmate on the basis of sex, race, age, socioeconomic level, and achievement level to form a contrast group. All children in a class where there was a visually handicapped child were asked to choose 5 desired companions from their classmates for each of 3 situations: working, leisure, and seating. A chi-square statistical analysis of the data revealed a significant difference in sociometric

status beyond the 0.001 level of confidence between the visually handicapped experimental group and the sighted control group. There was also a significant difference (at least at the 0.01 level) between each of 3 visual impairment categories and the control group, and a significant difference in sociometric status between visually handicapped children of different levels of achievement. Significant differences in sociometric status were also found between visually handicapped children being served by itinerant and resource room programs. None of the other variables examined (degree of impairment, grade level, sex, socioeconomic level, time spent in regular classrooms, and choice situations) revealed significant results. The author concludes that the condition of being visually handicapped, and thus different, results in low status and difficulties in social acceptance.

Hoover, R. E.

Visual efficiency as a criterion of service needs.

American Foundation for the Blind, *Research Bulletin No. 3*, 1963, 116-119.

An ophthalmologist gives his definition of visual efficiency as a complex of measurable visual characteristics which, when combined with other sensory and physical characteristics, provides an opportunity to utilize sight (opportunity implies motivation or incentive). Visual acuity plays only a part in the determination of visual efficiency.

Visual acuity may and should be measured at several distances of both far and near points. Visual versatility measurements should include optical power, accommodation, and convergence and divergence ability--even in pathological conditions. Visual capacity includes the measurement of the length of time, the amplitude and conditions for maintenance of visual functioning.

The measurement of other physical and sensory characteristics and the establishment of patterns of visual characteristics required for the performance of various tasks would permit the adaptation of visual efficiency patterns for specific visual activities.

Hopkins, K. D., & McGuire, L.

Mental measurement of the blind: The validity of the Wechsler intelligence scale for children.

International Journal of Education for the Blind, 1966, 15(3).

The purpose of the present study was to obtain evidence on the validity of comparability of the WISC as a measure of intelligence for blind children. The study revealed that despite the fact that the Hayes-Binet and WISC measure essentially the same abilities, and both yield normal distributions of IQ scores, the corresponding IQ scores are not comparable, i.e. there is a highly significant trend for WISC scores to be lower than H-B scores, the mean difference being 8.5 points. (The differences expected at the extremes would appear to be even larger since the standard deviations for the 2 scales are substantially different.) This study re-emphasizes that a high correlation and strong relationships between tests in no way insure comparable normative data. An analysis of variance of the subtests scale scores revealed a significant tendency for relatively inferior performance by the blind subjects on the comprehension subtests. This factor attenuates the implicit validity assumption of equal opportunity for learning and performing and suggests some general visual bias on this type of scale. Results also show a tendency for lower intercorrelations between subtests for the experimental sample, implying greater intra-individual differences in intelligences among the blind. No differences were found in subtest reliability between present sample and standardization data. It is recommended that users of intelligence test data be aware of the marked lack of interchangeability between WISC and Hayes-Binet scores and gear corresponding interpretations accordingly.

Hopkins, K. D., & McGuire, L.

IQ constancy and the blind child.

International Journal of Education for the Blind, 1967, 16(4).

The four-year constancy of IQ was investigated for a group of 30 blind children. The initial Hayes-Binet (H-B) IQ scores were much more comparable to subsequent WISC IQ scores than to the retest scores on the H-B, especially when actual IQ scores were considered. It is recommended that H-B scores be interpreted very cautiously since marked variation was noted between test and retest performance. For a high degree of IQ constancy on a test, 2 conditions must be evidenced: first, a large amount of lasting variance, which indicates stable individual differences are being assessed, must be present; this condition was met by the tests used in this study as demonstrated by the high stability coefficients; second, adequate normative data, minimizing fluctuations in the mean and standard deviation of the IQs from year to year, must be present. This latter would appear to have been the major factor which accounted for the wide IQ discrepancies on the H-B. The study has implications for the renorming of the H-B.

Hudelmayer, D.

Concept-attainment with blind children.

The Visually Handicapped, 1972, 1, 49.

The research should test in the area of nonverbal concept attainment, whether early visual deprivation has a general effect on the capacity of 9-15 year old blind children for information processing capacity. Forty congenitally blind or early blinded scholars were individually matched with two fully sighted according to sex, age, and verbal IQ. With auditory tasks no over-fortuitous difference between blind and sighted children was encountered. On the other hand the sighted mastered the tactile tasks very significantly better than the blind. This difference is not interpreted as genetically qualified but attributed to the effect of visualization.

Huff, R., & Franks, F.

Educational materials development in primary mathematics: Fractional parts of wholes.

Education of the Visually Handicapped, 1973, 5, 46-54.

Subjects: 9 beginners, 10 1st-graders, 10 2nd-graders. Each subject was tested individually in a series of manipulation (correctly placing rubber circles and fractional parts of circles in circular nests in plastic form-boards) and discrimination (of the "same or different," "which is the largest" type) tasks. Measures were taken of (a) the mean number of manipulation trials required to correctly complete the tasks (for each grade level); (b) percent of correct responses (mean for each grade) for each type of discrimination task. Results (a) decreased over grade levels, all differences being significant; (b) for same/different tasks percent increased with grade but only the difference between beginners and 2nd-grade was significant. For "which is largest" tasks the percent of correct responses only increased between beginners and 1st-grade and this difference was not significant. There were also several inconsistencies between grade levels. All subjects as-a-group failed to distinguish between 1/3 and 1/4 when placed in a nest in a form board. Perhaps superimposition would be a better method. Further research is required to see if preliminary training would help discrimination between 1/3 and 1/4.

Israel, L.

C.C.T.V. reading machines for visually handicapped persons: A guide to selection.

The New Outlook for the Blind, 1973, 67, 102-110.

Closed-circuit television reading machines are now available from

several sources, with different models offering a variety of features. Among those criteria to be considered in selecting a device for purchase, the following are suggested as being vitally important: magnification, focus reversed image, sharpness (brightness), clarity (contrast), movable viewing table, adjustable monitor (distance, weight, tilt) portability, accessories, monitor selections, aesthetics, warranty and service, long-term support, and user's manual and instructions.

Johnson, S.

Sources of agency referrals.

The New Outlook for the Blind, 1971, 65, 49-50.

In this article, the author discusses how to encourage more people to seek assistance, other than financial, from agencies serving the blind. It is felt that more public education is necessary, especially within the medical field; but the author points out that public education will never be the complete answer. Rather, she states that people remember what they see, and thus the utilization of community resources for clients, plus the integration of clients into community activities, would be more successful in making others aware of the services available through agencies for the blind. The benefits of a community-oriented program such as this would also be felt by the clients themselves, in giving a sense of participation in and belonging to a community group.

Johnston, B., & Corbett, M.

Orientation and mobility instruction for blind individuals functioning on a retarded level.

The New Outlook for the Blind, 1973, 67, 27-31.

Experience at the Orange Grove Center for the Retarded, Chattanooga, indicates that blind youths who are functioning on a retarded level can be taught orientation and mobility skills through an emphasis on very basic pre-cane skills and the addition of more intermediate steps in the standard teaching techniques.

Jones, J. W., & Collins, A. P.

Trends in program and pupil placement practices in the special education of visually handicapped children.

International Journal for the Education of the Blind, 1965, 14, 97-100.

Organizational patterns in school programs for the visually handicapped show an interesting change from a high percentage of special classes in 1946 to a very small percentage of children segregated in special classes in 1963. Resource rooms and itinerant teaching plans are used in a majority of programs.

Teachers in both residential and local school programs work with both blind and partially seeing children in combination units, and increasing numbers of programs include visually handicapped children with additional problems. The ability to use print materials rather than the degree of visual acuity is the basis for classification in most schools.

Jurmaa, J.

The spatial sense of the blind.

American Foundation for the Blind, *Research Bulletin No. 24*, 1972, 57-64.

Presents a research protocol with 3 major problem areas proposed for study: (a) intercorrelations among the various sense modalities of abilities for mental manipulation in space; (b) the transposition of sense images from one modality to another from the viewpoints of--extent of attempts, likelihood of success, and the degree of help such a transposition is in performing a task; (c) intercorrelations among spatial ability, transposition and some control variables. The experimental approach is briefly outlined.

Karnes, M. B., & Wollersheim, J. P.

An intensive differential diagnosis of partially seeing children to determine the implications of education.

Exceptional Children, 1963, 30, 17-25.

By use of a variety of psychological and educational instruments, highly relevant clinical information was obtained relating to the variable factors which influence successful learning of the children with partial vision. Implications of the study suggest the feasibility of a clinical type of teaching utilizing special methods and techniques to facilitate learning and achievement more in keeping with the potential abilities of the children acquired by a thorough interpretation of the individual strengths and weaknesses of the children.

Kay, L.

The sonic glasses evaluated.

The New Outlook for the Blind, 1973, 67, 7-11.

A precis of the findings of two questionnaires (169 items for the 94 users of the aid, 88 for the 21 trainers) to evaluate the ultrasonic binaural sensory aid for the blind, a mobility and orientation device invented by the author. The results, summarized in three lengthy tables, indicate that 88 percent of the users found the device useful and that only 20 percent of the trainers thought that their own training was inadequate.

Kay, L.

Sonic glasses for the blind--A progress report.

American Foundation for the Blind, *Research Bulletin No. 25*, 1973.

Sonic glasses are similar in appearance to optical glasses but work by the emission of VHF sounds which are "echoed" by reflection from the objects in the arc covered by the device (a cone of about 60 degrees). The pitch of the sound heard by the user is proportional to the distance of the object and the quality of the sound gives some indication of the nature of the object. The report is based on data from 31 instructors, 104 totally blind subjects (age range 11-55, average or above intelligence). Ten subjects were novice travelers, 74 trained in long cane, 20 trained with guide dogs. Training in the use of the glasses seemed to be a major variable--where training was good, so were performance and motivation. The sonic glasses greatly improve awareness of the environment and reduce the stress of travel, since with training the user learns to distinguish between the objects in his path. This includes people and thus the blind person can avoid embarrassing collisions, can judge the space between himself and fellow travelers and can sense spaces to move into. *Knowing* that he has encountered a *human* object he can ask the way if need be. The major problem in the case of the congenitally blind is one of perception--he cannot mentally visualize the world in 3D, or readily relate to the idea of space. Even the simple concept of direction may be confusing. However, the evaluation brings out 2 important facts. That almost all the teachers trained in teaching the use of sonic glasses wish to continue to do so. Success rate among subjects was over 90 percent--only 8 subjects dropped out (maybe because of inadequate teaching in this initial stage of introduction of the device).

Kederis, C. J., Nolan, C. Y., & Morris, J.

The use of controlled exposure devices to increase braille reading rates.

International Journal for the Education of the Blind, 1967, 16, 97-105.

This is a report of 2 studies using controlled exposure techniques to increase braille reading rates. In one study, familiar words, phrases, and short sentences were read at diminishing time intervals on a rapid-exposure device. In the other, literary material was read at increasing word rates on a pacing device.

Both studies used an experimental and control group of 15 matched subjects divided into reading rate levels (fast-slow). The experimental groups practiced reading one half hour/day for 20 consecutive school days. A monetary regard was used to control for motivation on the criterion tests. No significant effects of reading practice were found on pre- and post-reading tests. Motivational effects apparently accounted for the 24 percent average reduction of reading times in both studies.

Kenmore, J.

Helping blind persons to find and prepare for employment.

The New Outlook for the Blind, 1973, 67, 111-115.

Four kinds of job market surveys are recommended for discovering possible occupations for blind persons. The role of schools in promoting the success of blind youngsters when they enter the job market is fully discussed. Where schools fail, many countries start intermediary centers to prepare blind young people for the world of work. The role of the placement officer is emphasized as are the roles of agencies and government. Examples in each area are drawn from many countries around the world. Based on a speech given to a biennial conference of agencies and schools for the blind in France.

Kimura, M.

Perception of the compound figures by tactile motor-scanning.

(P.A. Vol. 49, No. 4, April 1973 from) *Japanese Journal of Psychology*, April 1972, Vol. V3(1), 1-12.

Investigated the mechanism by which the congenitally blind tactually perceive compound figures in which 2 or more simple, geometrically contoured figures are overlapped. A series of 11 experiments were performed with congenitally blind adults, normal seeing adults with eyes closed, persons blinded after birth and normal seeing children. Results show: (a) normal seeing adults, even with eyes closed, and those blinded after birth saw a compound figure as consisting of 2 or more simple, relatively large figures--called α type segregation--while congenitally blind subjects perceived it as consisting of many fragmented parts--called non α type segregation. (b) Young children with normal sight perceived figures with various types of non α type segregation, indicating that normal sight and visual experiences were not sufficient for attaining α type segregation. (c) The non α type segregation of the congenitally blind was weakened when size stimulus context, plus figure completion were varied.

Klimasinski, K.

An attempt to test the personality of the blind using the MMPI.

American Foundation for the Blind, *Research Bulletin No. 24*, 1972, 65-74.

The Polish version of the MMPI (550 items) was modified (342 items) and administered to a group of 30 blind men tested in groups of 4 or less, with the order of item presentation changed for each group. Half of the subjects had visual losses greater than 20/200 but did not differ on any MMPI scale from subjects with visual losses less than 20/200. All subjects were compared with MMPI norms based on 100 men with normal sight; statistically significant differences were obtained for 2 control keys plus 4 clinical scales. The difficulty in specifying the extent to which these differences reflect loss of sight or subject's social situation is noted.

Knight, J. J.

Mannerisms in the congenitally blind child.

The New Outlook for the Blind, 1972, 66, 297-302.

Describes mannerisms in the congenitally blind child as non-instrumental behaviors used in infancy as a means to reduce tension and

maintained afterwards when the child has not been able to substitute non-instrumental gross motor activities by acquisition of learned instrumental behavior. The sighted infant, during his normal development, learns to abandon non-instrumental gross motor activities and begins to acquire learned instrumental behavior. During the first two years of life, the blind child should receive special help; otherwise, some basic instrumental coping behaviors, especially reaching and crawling skills, may not be developed to their fullest potential.

Kuhn, J.

A comparison of teachers' attitudes toward blindness and exposure to blind children.

The New Outlook for the Blind, 1971, 65, 337-340.

In order to determine whether regular classroom teachers with experience teaching blind children would express more positive attitudes toward blindness than would teachers without this exposure to blind children, the "Attitudes to Blindness Scale" was given to 46 elementary school teachers. Twenty-eight of the teachers taught in a school with a resource room for blind children and had had a blind child in their regular classroom for at least 1 hr. per day; the other 18 teachers taught in a school located in the same district but which had no blind children enrolled. A comparison of the mean scores showed no significant differences between the 2 groups, although the mean scores of both groups (43) were approximately 10 points lower (thus indicating a more positive attitude toward blindness) than the mean scores of college students tested by Cowen, Underberg, and Verrillo (1958). A chi square analysis made on each question revealed no significant results. The author concludes that exposure to blind children does not necessarily mean that the teacher thus exposed will have a more positive attitude toward blindness than those teachers without the experience of teaching blind children. However, it seems apparent that the reverse conclusion is also indicated--i.e. that teachers who have never taught blind children do not necessarily have more negative attitudes toward blindness than teachers who have had experience with blind children.

Kumpe, R.

Preparation of blind prospective college students.

International Journal for the Education of the Blind, October 1968, XVIII.

One hundred two blind students, preparing to enter their first year at college or university, were divided into 2 groups. One group was given 10 weeks of special preparation for college; the control group received no special training. The training for the first group comprised practice with several skills, both academic and personal/social, which would lead to greater success in the university setting (e.g. writing term and research papers; taking notes; orientation and travel; discussions of personal and social problems; special resources for blind students, etc.). The evaluation of the program by the experimental group itself indicated that 39 percent felt it Very Helpful; 44 percent felt it of Some Help; and 17 percent felt it was No Help. The control group, asked to consider the value such a program might have been to them, felt that it would have been Very Helpful (43 percent); of Some Help (29 percent); or of No Help (28 percent). Comparison of academic performance of the 2 samples indicated that the special training had significant effect for the experimental sample, as 17 percent of them were in the first quartile academically as against only 7 percent of the control group. There was no significant difference between the groups in continuance in college to the end of the first year, but both groups showed an advantage in this area over the general first year population. No significant difference in grade point average was found between the groups.

Kurzhals, I. W.

What is "readiness" for the blind child?

International Journal for the Education of the Blind, October 1968, XVIII.

This article discusses "readiness" in terms of four general areas: physical readiness, mental readiness, social-emotional readiness, and psychological readiness. It is suggested that the blind child should manifest "readiness" in each of these areas before entering an educational setting. Once having entered a school, however, the instructional program must be geared to maintain the progress already made by the child and continue his growth and development. The program for blind children in the state of Utah (U.S.A.) is described; it is a developmental program for primary-aged children and is divided into learning areas: orientation and mobility; music and rhythm; exploratory time; language development; numerical development; and reading. The aim of such a program is to help the child to develop as a total person and to prepare him for later educational experiences.

Lairy, G. C., & Harrison-Novello, A.

The blind child and its parents: Congenital visual defect and the repercussion of family attitudes on the early development of the blind child.

American Foundation for the Blind, *Research Bulletin No. 25*, 1973, 1-25.

A study was made of legally blind children under 6 years old in Paris. The Maxfield-Bucholz Scale of Social Maturity was administered and the child observed in the presence of its parents, during extensive interviews. Performance was found to be related to family background and four patterns seemed to emerge. (1) Overall score normal, heterogeneous scatter between the five behavior categories: associated with accepting parents and, usually, younger siblings. Children encouraged to use residual vision to best advantage. (2) Speech very good; posture normal; autonomy, sensory-motor, sociability about half the normal score. Associated with over-protective parents underestimating the child's ability. These mothers became aware of their attitudes during interview and responded readily to guidance leading to spectacular improvement in the child. (3) Autonomy high, posture normal, sociability and language low, sensory-motor very low. Associated with mothers who had a long depressive period on discovery of blindness and never really got over it, though on the surface they appear to. They over-react and, determined that the child should be "normal," encourage activities like riding, walking. But they never play with the child or talk with him--these mothers do not respond to guidance since it arouses guilt feelings. (4) Very low overall score--genuinely multi-handicapped children.

Lairy, G. C. & Harrison-Novello, A.

Family attitudes and congenital visual deficit.

Psychological Abstracts, August 1973, 50(2), No. 3256.

Suggests that appropriate parental reactions to handicaps of a child have important consequences for the psychological development of the child. Developmental problems are reviewed. Characteristics of blind or nearly blind children examined by the authors are described. Results on a modified version of the Maxfield-Bucholz social development scale, observations of parent child interactions, and discussions with parents suggest a classification of these children into four groups with different developmental profiles.

(French: "Interpretation," Vol. 5(2-3), April 1971, pp. 157-186.)

Le Zak, R. J., & Starbuck, H. B.

Identification of children with speech disorders in a residential school for the blind.

International Journal for the Education of the Blind, 1964, 14, 8-12.

The 173 children studied ranged in age from five to 21 years. The oral stimulation technique was utilized and descriptive ratings were

for normal and deviant responses of (a) articulation, (b) voice characteristics, and (c) rhythm. Speech disorders were evident in 50 percent of the children with articulation disorders in the highest percentage, then voice, nonfluency, and multiple disorders in decreasing order. Findings suggested the need for formal speech therapy programs to develop earlier speech proficiency. These programs would be supplemented by classroom speech improvement programs to facilitate maximum communicative potential of blind students.

Levitt, A. L., Willerman, L. I., Rosenbaum, A. L., & Levitt, M.

Intelligence of retinoblastoma patients and their siblings.

Child Development, 1972, 43, 939-948.

Compared 25 sighted and 19 blind retinoblastoma patients with their normal siblings (n = 59) on the WAIS, WISC, Stanford Binet Intelligence Scale or Williams Intelligence Scale for Children with Defective Vision. Subjects blinded from the disease average 10 IQ points above their siblings while the sighted subjects with both eyes affected by the disease were inferior to their controls. Unilaterally affected subjects did not differ from their controls. It is concluded that while retinoblastoma per se is not associated with intellectual superiority or inferiority, retinoblastoma associated with blindness may result in selective cognitive superiority.

Lindlay, S.

Kinaesthetic perception in early-blind adults.

American Foundation for the Blind, *Research Bulletin No. 25*, 1973, 175-193.

Twenty early-blind subjects were matched by age and sex with 20 sighted subjects, aged 16-45. Subjects were asked to repeat arm-movement trajectories, presented to them as drawings. Each subject had 40 trajectories, the order of presentation being random for each subject. The same order of presentation was used to make a weighted trial, in which the pencil used by the subject to record his response was weighted with lead-shot. Equal numbers of subjects began with weighted/unweighted, equal numbers started with preferred/non-preferred hand. Arms were alternated every 10 trials. Two scores were recorded: (1) position score--the magnitude of error in locating the target position; (2) movement score--the distance moved relative to the length of the trajectory. It was found that early blind subjects were significantly more accurate than sighted subjects in reproducing movement length, with no difference between the groups on position scores. Weighting the pencils made no difference to the results. There was a significant loss of accuracy over the 40 trials--possibly because there was no feedback on the accuracy of the responses made. The only view which can explain how early blind are better on arm movement, but doesn't lead to expectation of superior performance in other parameters of kinaesthetic perception, seems to be one involving timing, blind people characteristically reporting that they judge distance by timing. At any rate the evidence suggests that an adequate, or even superior, model of personal space can be developed without vision.

Linn, M.

An experiential science curriculum for the visually handicapped.

Exceptional Children, 1972, 39, 37-43.

Describes the adaptation and evaluation of a materials-centered experiential curriculum. The adaptations of both the physical and the life science units can be used in classes with one or two visually impaired students and in classes of all visually impaired students. The programs involve firsthand experience with objects and live organisms. Evaluation measures were designed to assess the major objectives of each unit in the program. Classroom trials (4 classes N = 48) of two of the adapted units revealed that visually impaired students made significant gains in understanding both content and process objectives of the units.

Linvill, J. G., & Bliss, J. C.

A direct-translation reading aid for the blind.

Stanford Electronics Laboratories, Stanford Univ., Stanford, Calif. (SU-SEL-65-055, Technical Report No. 4819-1).

A reading device for the blind is proposed in which a facsimile of ordinary printed material is presented tactually. The tactile image is presented by a dense array of pins which can be made individually to vibrate through perforations in a plate on which the finger of the reader is rested.

In the arrangement proposed, the image of ordinary printed matter is focused on an array of photocells which are coupled one-to-one to piezoelectric reeds which drive the image-producing pins. Preliminary designs of this arrangement have been tested, and engineering considerations of the design are presented.

Successful reading tests with blind subjects are reported in which a computer controller simulates the optical portion of the system. The tactile images presented on a field of 96 piezoelectrically driven pins have been readable by the three subjects tested.

Lissonde, B., & Porot, M.

Visual deficiency and mental deficiency.

Review de Neuropsychiatrie Infantile et d'Hygiene Mentale de l'Enfance, 1971, 19, 1-19.

Analyzes elements common to children who suffer both visual and mental defects. Those with relatively high intelligence generally have a visual acuity of less than 1-10. These subjects display obvious difficulty in motor tests, and are usually of calm, passive and introverted character. It is noted that differences exist between those who are blind from birth and those who later become blind, the former being better able to cope with their handicap. Parents' attitudes play a primary role in this context, because retational difficulties are present in these doubly handicapped children. A concrete adaptation of L. Corman's "Patte Noir" test is demonstrated, suggesting new perspectives in the exploration of blind children's personalities.

Mayadas, N. S.

Role expectations and performance of blind children: Practice and implications.

Education of the Visually Handicapped, 1972, IV, 45-52.

The role performance of 56 blind adolescent subjects were compared with the role expectations of (1) significant others, (2) the blind child's perception of significant-other expectations, (3) blind child's self-expectations, and (4) expectations of persons who were "strangers" to blindness. All blind subjects and their significant others, plus a random sample of strangers, were administered questionnaires to score the variables in expectation categories. In addition, performance behaviors were scored from a daily count of actual behaviors occurring over a 2-week period. Results indicated that role synchrony existed between performance of blind subjects and (1) the expectations of significant others, (2) the subject's perception of significant other expectations, and (3) the subject's self-expectations; role asynchrony was indicated between expectations of persons who were strangers to the blind and the performance of blind subjects. Thus role expectations, except for random stranger expectations, were found to be significant partial predictors of performance.

Mersi, F.

Braille for partially seeing.

The Visually Handicapped, 1972, 1, 32-33.

Braille-shorthand is an important aid for partially seeing pupils, students and office workers. In individual cases braille longhand writing can be a means for mentally retarded partially seeing to develop a self decipherable writing. The condition in each case is however, that braille writing is adapted to the special requirements of the group in which it is applied. The best solution would be embossed braille print with contrast in color, which for example could be accomplished by means of microencapsuled film. It would meet especially the need of the "mix technicians" and the correctors. In the majority of cases a braille writing machine, that stamps only visually well perceptible holes, would suffice. Visually adapted braille is a help and advantage in the case of the preventive learning of the braille system. As the braille writing machine is easily handled, even some manually handicapped persons could thus be helped eventually. The issue of all publications in punched braille with color contrast would be advantageous for many readers. Being dependent on braille is not in all cases identical with the suitability of applying teaching methods for the blind.

Miller, W. H.

Manifest anxiety in visually-impaired adolescents.

Education of the Visually Handicapped, 1970, II(3), 91-95.

Hardy's Anxiety Scale for the Blind was administered to 50 pupils at a residential school for the blind who were placed in grades 9-12 and in special classes. The purpose was to examine relative levels of manifest anxiety between students in grades 9 and 10, 11 and 12, and special classes, and between totally blind and partially sighted students. No significant differences were found when special classes were compared with grades 9 and 10, 11 and 12, nor when totally blind and partially sighted subjects were compared. However, when levels of anxiety for those students in grades 9 and 10, and 11 and 12 were compared, it was found that the anxiety level of 11th and 12th grade subjects was significantly greater ($P = 0.05$). An examination of specific responses was also made, and it was revealed that the majority of anxiety responses centered around the areas of social competences, personal appearance, and adjustment to blindness.

Miller, W. H., & Porter, J. E.

Read it. Say it fast.--The use of Distar Instructional Systems with visually impaired children.

Education of the Visually Handicapped, 1973, V(1), 1-8.

Distar is a teaching program with three sequenced levels in reading and arithmetic, and two levels in language, with aids, books and games for each program. The major premise of Engelmann et al.--the originators of Distar--was that any child can learn if he participates in logically sequenced learning experiences. Distar was tested on visually handicapped children in a non-graded primary school after a sequence of seminars and workshops with the teachers. Adaptations made: (a) for Partially Sighted--(1) Original print stimuli were enlarged to 4x and gradually reduced to 2x over 40 lessons. Similarly with spacing. (2) Visual embellishments to attract pupils attention in the standard text were excluded. "Check-test stimuli" were simplified. (3) Hand signals (cues for response) were exaggerated. (b) for Totally Blind--(1) Standard texts using varying sizes and contexts randomly distributed over the page were changed to standard braille and the page divided into four quadrants. (2) Standard texts use small letters for "silent" letters. For the blind the words were spelled as they sound and were accompanied in class by verbal explanation. (3) Auditory rather than visual cues, were used, e.g. clicking fingers instead of raising hand as cue to start. The program was concluded to be successful and extended now to multiple handicapped as a result.

Milstead, J. R.

Modification of echolalic speech in a blind, behaviorally deficient child using parental contingency management.

Journal of Communications Disorders, 1972, 5(3), 275-279.

Details the case history and treatment of an 8 year old, blind, behaviorally deficient boy whose echolalic speech was modified through a contingency management program using the subject's parents as the primary therapists. The frequency of nonecholalic responses increased as a result of treatment, and the change appeared stable.

Mishchenko, M. N.

Quint's method of the investigation of the facial motor phenomena of blind children and youth.

Nevropatologia i Psikhiatria, 1936, 5, 1379-1386 (in Russian); *Psychological Abstracts*, 1937, 11, Item 1254.

"The action of the loss of the visual receptor on facial motor phenomena was investigated, using Quint's method, consisting of 26 motor tests. Comparing blind children with normal ones, a decrease of facial activity was observed. The visual receptor is the main factor in the development and formation of the facial motor experience, the other factors being: age, time of the loss of vision, and constitution. The loss of the visual receptor excludes the possibility of forming facial movements by imitation. As a substitute for vision there are used the proprioceptive motor formations. The correlation between facial motor activity and constitution is the same as between general motor activity and constitution."

Mishchenko, M. N.

Peculiarities of voluntary movements of the facial muscles in blind people.

Sovetskaia Nevropatologia, 1935, 7, 121-132 (in Russian); *Psychological Abstracts*, 1936, 10, Item 246.

"The peculiarities of voluntary movements of the facial muscles of blind people, investigated by Quint's method, are as follows: facial motor activity in the blind is reduced below that of seeing people; asynchronic movements are more difficult for the blind than are synchronic ones."

Moore, M.

Development of number concepts in blind children.

Education of the Visually Handicapped, 1973, 5(3), 65-71.

Blind children have often not developed the logical cognitive processes on which mathematics is based, before they enter school. Basic to an understanding of number is the understanding of the conservation of number, in which classification and seriation skills are involved. Blind children tend to be "experientially deprived"--missing out on the "helping" tasks at home which develop basic concepts. Many experiences, formal and informal, must be provided for the blind child in school to develop skills of matching, classification and seriation before he is ready for the development of mathematical concepts. A hierarchy of skills has been developed such that mastery of a particular task in the hierarchy presupposes mastery of previous concepts and skills. Failure to learn may not be attributable to poor teaching or inability to learn but to choosing a task which is at a higher level of conceptual development than the child has reached. A summary is presented of a hierarchically organized sequence of tasks adapted for the blind leading to an understanding of numbers and the number system.

Morris, J. E., & Nolan, C. Y.

Minimum sizes for areal type tactual symbols.

International Journal for the Education of the Blind, 1963, 13, 48-51.

Purposes of this study were to establish minimum outer dimensions for areal symbols and to determine whether grade differences exist in the minimum sizes at which students can recognize them.

Minimum outer dimensions were established and a notable grade level inequity in identification was evident as symbols diminished in size. Children in grades four through seven require large symbols for easy recognition. Graphics for the blind should be constructed according to grade level use.

Myers, W. A.

Color discriminability for partially seeing children.

Exceptional Children, 1971, 38, 223-228.

Thirty 8-12 year old myopic children without color vision problems (acuity 20/70-20/200 in the best corrected eye) viewed Snellen "E"s in five different colors against differing backgrounds of the same colors. A black on white combination served as a control condition. "E" measured the distance at which subject could identify the direction of the "E" as well as the distance at which the subject reported greater clarity; the results of both measurements were comparable. Low contrast combinations were poorer than the control ($p < 0.05$). A few combinations (e.g. yellow on black and blue) were non-significantly better than the control. The relative ranking of all combinations is reported. The study is significant in that it used controlled colors (Munsell) and statistical techniques.

Naddeo, C. L., & Curtis, S. W.

Some effects of the disorientation of tactual-kinesthesia.

International Journal for the Education of the Blind, 1968, XVIII.

The missing parts of 14 objects of the Haptic Intelligence Scale were identified by 2 groups of sighted blindfolded Ss. The Ss in one group received the objects with their hands positioned normally in front of them. The Ss in the other group received the objects with their hands positioned in front of them, crossed at the wrists and inverted with thumbs down, to provide a condition of distorted tactile-kinesthetic perception. The Ss in the control group required less time and made fewer errors in identification than the Ss in the experimental group. The differences between the groups were statistically significant. Such results have implications for both practical testing procedures and philosophic considerations regarding the appraisal of intelligence, where sensory and perceptive channels are distorted in quality rather than reduced in quantity (from threshold).

Napier, G.

A writing vocabulary study relative to braille contractions to be mastered by primary level children.

Education of the Visually Handicapped, 1973, V(3), 74-78.

Outlines the difficulties in learning braille--especially in writing, with so many rules and contractions to be kept in mind at each step. This study hopes to find (1) those words that have the highest functional value in meeting the child's needs; (2) whole word contractions and their sequence of introduction among the words of (1) above; (3) those part-word contractions with the highest frequency (to determine the most functional). Method: Used 5 published vocabularies to determine which words occurred most frequently and which contractions among those words occur most frequently. Vocabularies used were relevant to primary graders rather than adults, with an emphasis on

writing rather than reading. All words containing braille contractions were noted. Those appearing in all 5 were considered the most crucial ones to learn first--since they are deemed important by 5 authorities (Category (1) words). Next important are those occurring in 4 vocabularies (Category (2)) and so on. 7560 words were studied. Of these 4472 contained contractions. When duplications are removed 2158 words remain--these constitute the basis of the study and have been designated the Composite Vocabulary. Of 190 braille contractions only 169 occur in the Composite Vocabulary; 129 are whole word signs, 40 are part-word signs. The first 11 part-word signs constitute 74 percent of all part-word signs. A teacher who uses these 11 part-word signs and the 63 whole-word signs from Category (1) words has the core of words with which to launch initial instruction in writing braille.

National Committee for Research in Ophthalmology and Blindness.

Proceedings of the symposium on research in blindness and severe visual impairment.

New York: American Foundation for the Blind, 1964. 113 pp.

Attention in eye research has shifted increasingly from visual acuity to visual efficiency. The implications of the relevant factors involved for ophthalmologists and the coordination of their work with other disciplines were the primary topics of the symposium. Definitions, registration reporting techniques, coding procedures, and technological development were other themes for discussion.

Nolan, C. Y.

Reading and listening in learning by the blind.

Exceptional Children, 1963, 29, 313-316.

In an effort to compare learning attained through listening and through braille reading, 70 braille readers were divided into groups designated as listening, braille reading, and control. Learning was tested by a 36-item, four-alternative multiple choice test. Numerous methodological factors were identified as well as significant variables which appear to influence the relative effectiveness of the two modes of learning. The possibility that an overemphasis on braille reading presents an obstacle in the education of blind children is a relevant implication.

Nolan, C. Y.

Blind children: Degree of vision, mode of reading--a 1963 replication.

The New Outlook for the Blind, 1965, 59, 233-238.

Summary of differences: Comparison of 1960-1963 data.

1. The total number of legally blind children registered with the American Printing House increased by 2,536 children during the period. Of these, 2,072 were enrolled in local school programs and 464 were enrolled in residential school programs.

2. Between 1960 and 1963 the percentage of students listed as braille readers decreased 5 percent and the percentage of students listed as print readers increased 5 percent. This appears due primarily to a dramatic increase in the proportions of residential school students in visual categories I-IV who are listed as print readers.

3. In 1963, 12 percent more residential school students possessing object perception or better were registered as print readers.

4. The number of legally blind students classed as ungraded in 1963 was 1,348. This was a 50 percent increase over the number of students so reported in 1960.

5. The accumulation of braille readers in kindergarten and grade 1, so evident in the 1960 data, does not occur in the 1963 data. The 50 percent increase in the number of braille readers classed as "ungraded" suggests that this

peak in the 1960 distribution for grades was partly the result of an accumulation of children of limited academic aptitude.

Nolan, C. Y., & Morris, J. E.

Development and validation of the roughness discrimination test.

International Journal of Education for the Blind, 1965, XV(1).

The Roughness Discrimination Test (RDT) was developed as a reading readiness test for braille after preliminary research revealed the growth of ability to make tactual discriminations. The final version of the RDT is composed of a set of 69 cards upon each of which is mounted 4 pieces of sandpaper. Of these, 3 pieces are alike and one is different, being rougher or coarser than the others. The task for the student is to find the sandpaper that feels different from the others. The test was found to have a split-half reliability coefficient of 0.94. Only items having a difficulty index between 0.10 and 0.85 and an item-test correlation significant at the 5 percent level or higher were retained in the final version. No significant differences were found between the sexes in their ability to make tactual discriminations and early research indicated that there is only a moderate relationship between discrimination scores and IQ. Both predictive and concurrent validity for the test were determined. Predictive validity was determined using first-grade students by testing them with the RDT at the first of the school year and then testing their reading at the end of the year. It was found that the RDT correctly predicted whether these students would be in the upper or lower half of the group, 70 percent of the time when reading errors was the criterion and 75 percent of the time when reading time was the criterion. Concurrent validity was determined for second grade students by correlating RDT scores with reading time and reading error scores. Definite but small relationships significant at the 5 percent level of confidence were found for both criteria.

Nolan, C. Y., & Morris, J. E.

The Japanese abacus as a computational aid for blind children.

Exceptional Children, 1964, 31, 15-17.

Forty-two junior high students were pretested for skill in computation of whole and decimal numbers by any method they chose. Continuous instruction and practice in the use of the soroban was given for eight months, and post-testing followed. Statistically significant increases in computing speed and accuracy were demonstrated which verifies that the soroban is a practical and efficient approach in overcoming the previous computational problems of blind children.

Packard, B.

A technique for developing perceptual materials for the blind.

American Foundation for the Blind, *Research Bulletin No. 25*, 1973, 253-255.

Describes the translation into tactile kinesthetic tasks of selected pages of the Marianne Frostig Program for the Development of Visual Perception by construction of raised line work sheets. Greater use of existing knowledge on learning disabilities and perceptual handicaps in sighted children is recommended for workers with the blind.

Pape, R.

The effect of visual defects in education and at work.

The Visually Handicapped, 1972, 1, 24.

Recent studies and inquiries have shown that even small visual defects have a considerable effect on education and vocation. By results of experiments with partially seeing and one-eyed persons factors of impediments are made explicit, and they are applied to the manifold group of the partially seeing in the narrower sense of the word.

Physiological and optical mechanisms are discussed, as well as the limited possibilities of optical aids. It is pointed out that in each individual case an experienced oculist had to be called upon to explain the degree of impairment and the applicableness of optical aids.

Patton, W. E.

Research on criteria for measuring mobility readiness of adventitiously blind adults.

The New Outlook for the Blind, 1970, 64, 73-80.

This research on the dynamics of readiness for mobility service had 2 major research goals: to attempt to identify specific dynamic factors of readiness of adventitiously blind adults, and to construct an instrument for measuring total readiness. Fourteen criteria were found to have a positive relationship to both the readiness score and the actual subsequent performance score. A readiness instrument composed of 8 criteria was found to have a positive correlation with performance, significant at less than the 0.01 level. This research study appears to have identified important specific factors related to mobility readiness. Although the relationship between the resulting research instrument and performance does suggest its usefulness in assessing readiness, further research is indicated.

Pfeiffer, H.

Investigations of the self-image in visually handicapped youths.

Heil Padagogik, 1972, 41, 266-272.

Studied the self-image of 24 visually handicapped high school students by asking them to describe "how I am" and "how I would like to be." Results were evaluated by categorizing 12 basic elements contained in the essays, e.g. mentioning of interests, handicaps, satisfaction, or plans for the future. Evaluation indicates that the method of assessment should be strengthened by questionnaire scales to measure self-image more objectively. No clues for a specific self-image in visually handicapped students was found in the sample. The use of control groups is suggested in further research.

Postel, J., Caillon, N., & Neu, C.

Oral language of the blind child.

Revue de Neuropsychiatrie Infantile et d'Hygiene Mentale de l'Enfance, 1971, 19, 21-32.

Distinguishes blind children's speech from that of sighted children in 2 ways: (1) at the articulation level disturbances are most frequent because imitation of phonatory movements are missing, particularly those which play a part in facial expression; (2) and at the expression and content level, verbalism is found in 50 percent of blind children. This verbalism decreases in proportion as, during language learning, reliance on concrete tactile examples increases. The importance is noted of affective development, especially the child's early relationship with his mother, whose attitudes regarding the blindness of her child may have a greater influence on his language development than the sensory handicap itself.

Postel, J., G'stell-Jeannot, M. C., Krief, J., & Postel, M.

Study of an initial ten cases of tactile dyslexia in children blind from birth.

Review de Neuropsychiatrie Infantile et d'Hygiene Mentale de l'Enfance, 1972, 20, 733.

Notes that tactile dyslexia has characteristics similar to visual dyslexia. The distinguishing features are only those specific to blindness and tactile perception. Tests used for sighted dyslexic children had to be adapted for blind children. Graphic recording of the movements of digital reading showed that these were disorganized with numerous vertical and reversing movements, indicating major difficulties in motor coordination. It was confirmed that dyslexia can

affect the reading and writing of linguistic signs whose material basis and perception have no link with the sphere of vision.

Priest, H. F.

Preliminary report on research completed in 1966 using the Kay Ultra Aid for the blind.

American Foundation for the Blind, *Research Bulletin No. 17*, 1968, 83-90.

This experiment involved the use of the Kay Ultra Aid by 24 subjects over a period of about 13 weeks. For the purposes of comparing different sorts of training, the sample was split into three groups: one received training with movement, another received training with no movement, and the third group received no training. After the training sessions all subjects made approximately 2,000 judgments, spread over 12 to 20 half-hour sessions, of the size and distance of test objects. In general, distance judgments were much more precise than size judgments and they also were less affected by changes in the total stimulus situation. In particular, perceptual constancy, a main interest of this study, was found to operate more with distance than with size judgments. Differential training had little or no effect, probably because the training period was so brief.

Proscia, V. A., Silver, S., & Zumalt, L. E.

Joint enterprise undertaken between two centers for development and evaluation of a tactile communication aid for deaf-blind persons.

American Foundation for the Blind, *Research Bulletin No. 25*, 1973, 205-211.

The TAC-COM is a vibro-tactile communication system developed by the M.I.T. Sensory Aids Evaluation and Development Center. It consists of a sender and receiver, utilizing induction principles as the communication link. Induction loops are set up in the location (house, factory, etc.). The receiver is worn in the person's pocket and vibrates when it receives a signal from the induction field. The length of vibration can be varied according to a pre-selected code. The TAC-COM was evaluated as (1) a fire alarm, (2) doorbell system, (3) end-of-line indicator on typewriter or Perkins machine, (4) mobility aid device, and (5) general communication systems, e.g. time-clock, office call, telephone ring. All these were found effective and plans are under way to investigate other uses.

Randall, T. J., & Springer, D.

Optical aids: An interdisciplinary prescription.

The New Outlook for the Blind, 1973, 67, 12-19.

The roles of the optometrist who prescribes low vision aids to partially sighted persons and other professionals who provide training and follow-up services are related to the successful use of such aids. The necessity of acquiring general, non-optometric information concerning the prescription and the uses to which it will be put by the patient is emphasized. In an informal study involving 25 patients it was found that 8 had stopped using their prescribed aid. Factors affecting success of the aid prescription: (i) vocational change; (ii) vision change; (iii) unmet vision needs; (iv) motivation; (v) type of prescription; (vi) training. When an optical aid program incorporates an effective training program and follow up care scheme, these factors become less significant hindrances to the successful utilization of optical aids in vocational training and/or educational programs.

Rogow, S. M.

Language acquisition and the blind retarded child.

Education of the Visually Handicapped, 1972, IV, 36-40.

The author reports on a 3-year study of the speech patterns of a non-verbal nine year old blind girl. These speech patterns, consisting of, for example, refusals, demands, or repetitions of nonsense syllables, indicated that while language was comprehended by the child in terms of its syntactic and semantic aspects, it was devoid of its social function as a means of communication. Most of the child's speech concerned an action or a need; her concerns were related solely to herself and her preoccupation with her own feelings. Subjects about which the child had intense feelings were never referred to directly; when after 2 years she was able to verbalize these, they were disguised by expressing the opposite of what she actually felt. The author concludes that failure to speak, or failure to use meaningful speech, does not indicate that a child has not acquired linguistic competence. Rather, it reveals social isolation and experiential deprivation, which robs language of its function as a means of social interaction and communication.

Schale, F. C.

Exploring the potential of the monocular blind for faster reading.

Academic Therapy, (Sum.), 1972, 7(4), 401-410.

Tested two predetermined gifted speed readers on their ability to read and comprehend a page at a glance with one eye covered as a means of evaluating the same potential for the monocularly blind. The phenomenal abilities of the two subjects are described in detail and the relationship to eidectic memory is discussed. Both subjects, using only the right eye, were able to scan non-fictional articles of general interest at page-at-a-glance rates of less than one second per page with excellent comprehension. The factors involved in this performance are examined. It is concluded, by implication, that subjects with monocular vision and a similar combination of factors could develop similar phenomenal reading abilities on appropriate materials.

Schiff, W., & Isikow, H.

Stimulus redundancy in the tactile perception of histograms.

International Journal for the Education of the Blind, 1966, XVI(1).

An attempt was made to evaluate the relative effectiveness of several different ways of presenting tactile histograms for interpretation by blind persons. The materials varied in the size of differences in histogram bar-length, regularity of histogram, tactile quality of information indicating bar-length (mode), and redundancy of stimulus information. Forty blind high school students matched for IQ across conditions served as subjects.

Except for tactile quality and stimulus redundancy, all variables had significant effects on response time. Most interactions of the variables also proved significant. Tactile quality (mode of presentation) and redundancy had no independent significant effects on error scores but was significant in interaction with "difficulty" variables, with the most redundant presentation providing fewest errors when size differences were small. When size differences were moderate or large, different textures or outlines were quite effective means of indicating different areas. The time and error measures were relatively independent of one another, as indicated by a non-significant correlation of +0.23. Practical considerations of the findings bearing on preparation of tactile materials for blind students were discussed, as were implications for perceptual theory, and research techniques with tactile materials.

Singer, J. L., & Streiner, B. F.

Imaginative content in the dreams and fantasy play of blind and sighted children.

Perceptual and Motor Skills, 1966, 22, 475-482.

In order to test hypotheses growing out of a consideration of the role of vision in the development of a differentiated capacity for imagination, 20 pairs of otherwise matched blind and sighted children (aged 8 to 12) were studied. Interviews and spontaneous accounts of their play, fantasies, and dreams were recorded and rated independently by judges for Imaginativeness. Results indicated that sighted children proved more imaginative in all 3 areas, with blind children showing generally a concrete and limited fantasy content except for their greater reliance on imaginary companions. The author suggests that in view of these findings special attention to the training of the blind in imaginative story-telling and practice of fantasy play would be desirable.

Slar, M. J., & Rampulla, J.

Decreasing inappropriate classroom behavior of a multiply handicapped blind student.

Education of the Visually Handicapped, 1973, 5(3), 71-74.

Immediate token reinforcement, coupled with peer pressure was used to decrease inappropriate clapping behavior. A 20-year old blind subject with learning disabilities, mental retardation, social and emotional problems. Due to her desire for attention she had not learned to function as a contributing member of a group in the class. Tokens were earned, first, for each 20 minute period in which she refrained from clapping her hands. Three tokens earned five and each member of her class a bag of sweets. Next the period was increased to 30 minutes. Finally tokens were given at various intervals with a bonus of three tokens if subject did not clap at all during the 2-hour observation period. Inappropriate hand clapping decreased considerably and was virtually eliminated. Moreover, this decrease was sufficient to enable appropriate learning behavior to occur. Because subject was successful in this task she began to shine--this was reflected in her work, behavior and self-image. Class members began to accept her. When it was suggested to her that her rocking could also be reduced this occurred without reinforcement.

Smith, B. F.

The social education of deaf-blind children at Perkins School for the Blind.

The New Outlook for the Blind, 1966, 60, 183-186.

The author describes the methods by which deaf-blind children at Perkins School are helped to develop independence and social awareness, by examining the roles played by the adults involved in the children's training. These adults are: (1) the Attendants (involved in direct care of the deaf-blind children; act as companions; help the children to interact meaningfully with the blind children among whom they live); (2) the Housemother (supervises the work of the attendants; directs household routine of the children); (3) the Liaison Officer (helps resolve any conflicts arising among the team of adults on the staff); (4) the Principal (supervises and coordinates activities of attendants and housemothers; reviews problems with adult staff and suggests solutions); and (5) the Orientation Committee (responsible for the continuing inservice training of attendants and housemothers). A deaf-blind child's progress through the school is described with attention to the parts played by each of the staff in the child's social development.

Snyder, T., & Kesselman, M.

Teaching English as a second language to blind people.

The New Outlook for the Blind, 1972, 66, 161-166.

A method of teaching English as a second language to the visually handicapped, using initially the aural-oral method (all training concerned with mastering the sound system of English before attempting to read or write it) is described. Extensive use is made of tape recorders, tactile stimulation, and lessons whose content encourages the learning of the skills of daily living (mobility, gestures, social relations, handling money, etc.). It is observed that: (1) blind people learn a second language best in intimate, monolingual settings; (2) vocational motivation stimulates the most incentive to learn English; (3) both educated and uneducated blind students can demonstrate exceptional ability to learn a new language; and (4) lack of visual aids is not a handicap to learning, but the blind individual is aided by tactile stimulation during the learning session. Five case histories are included.

Stein, L., & Green, M. B.

Problems in managing the young deaf-blind children.

Exceptional Children, 1972, 38(6), 481-484.

Attempts to develop some general concepts regarding the early management of deaf-blind children and the help that can be offered their parents. Looks at the medical problems--especially of the victims of maternal rubella, and the difficulties the parents encounter in dealing with their children. Emphasizes the need for early and long-term psychoeducational management of such children and considers 4 programs for meeting their needs: (1) an early management program emphasizing psychoeducational management co-jointly with medical care should be designed to identify and train the child who is non-ambulatory, delayed in self-care skills and whose potential for learning has not been determined; (2) day programs for abulatory deaf-blind children with basic self-care skills and a determined learning potential; (3) residential programs for those who are ambulatory, possess self-care skills and show signs of learning potential that can best be developed through concentrated residential teaching; (4) custodial programs for severely impaired children who have not demonstrated any learning potential. Realization of these goals is dependent on interdisciplinary coordination of the medical professions, special education systems and state level agencies.

Stephens, B.

Cognitive processes in the visually impaired.

Education of the Visually Handicapped, 1972, IV(4), 106-111.

An outline of the Piagetian theory of development. Cognitive development occurs as a result of interaction with the universe. In the normal child, visual activity plays a very important role but the blind child must depend on ears, nose, touch, smell. The origins of intelligence lie in the sensory-motor period. This stage is not replaced by subsequent stages but is extended and incorporated into the later, more complex thought processes. The blind child is greatly hampered in this stage in development of sensorimotor schemas and in general coordination. Verbal coordination cannot compensate for this. Action learning is vital before the child can progress to conceptual, concrete operations and formal operations stages of thought/cognitive development. Unless blind children have experienced the concrete world and involved their bodies in acting on it, true concepts elude them. A need is stressed for tactual, perceptual knowledge of objects in order to counterbalance the negative effects of visual deprivation.

Streitfeld, J. W., & Avery, C. D.

The WAIS and HIS tests as predictors of academic achievement in a residential school for the blind.

International Journal for the Education of the Blind, 1968, XVIII(3).

This study is concerned with determining whether verbal achievement as measured by the Verbal Scale of the WAIS (Wechsler Adult Intelligence Scale), or performance IQ as measured by the HIS (Haptic Intelligence Scale), is more predictive of academic success for the blind. The Ss were 31 students, 17 male and 14 female, all students at a residential school for blind children. The WAIS and the HIS were administered to all Ss; a rating scale (1 to 14) based upon teachers' ratings and grades was devised to rate each Ss' academic achievement, for each individual school subject and for overall performance (including the 4 previous years). Results indicated: (1) The mean IQ for the present sample was slightly below standardization groups --for the HIS the difference was significant at the 0.01 level. (2) For the totally blind, the WAIS and the HIS are equally good at predicting grades. (3) For the partially sighted, the WAIS Verbal Scale appears to be a better predictor, perhaps because those with some sight are less likely to develop their tactile and kinesthetic skills and are thus at a disadvantage when blindfolded for the HIS test, thus confounding the resulting score.

Sykes, K. C.

A comparison of the effectiveness of standard print and large print in facilitating the reading skills of visually impaired students.

Education of the Visually Handicapped, 1971, III(4), 97-105.

In order to determine whether standard print is equally or more effective than large print in determining reading ability, 41 visually impaired students, 28 boys and 13 girls, ranging in age from 13-20 years, were given 2 of the forms of Series 2 of the Davis Reading Test. The Ss were free to choose their reading position, reading distance, lighting, and optical or non-optical reading aids. The tests were administered twice, once using standard print and once using large print. Analysis of the data obtained (utilizing a two-tailed t-test and analysis of variance) indicated that the Ss performed as well in standard print as in large print on measures of comprehension and reading speed. Large print, however, was apparently less fatiguing to read than standard print, possibly because of the students' greater familiarity and practice with large print materials. Visual acuity was not related to performance on the measure of comprehension, but those students with high acuities were able to read both standard and large print faster, and experienced progressively less visual fatigue on large print.

Sykes, K.

Print reading for visually handicapped children.

Education of the Visually Handicapped, 1972, IV(3), 71-75.

Most pupils who are legally blind do have some residual vision which tends to be ignored. It is very important, with the present trend towards integration of blind into ordinary schools, that pupils are encouraged to read ink-print wherever possible, especially standard ink-print so that the pupil can use the same materials as his peers. Each child should have a desk of the right size, to minimize general fatigue; his own lamp which he can alter in intensity and position; and the optical aids appropriate (plus training in their use and frequent re-evaluation). Readiness for reading is very important--many visually handicapped children are developmentally delayed and need training in verbal/auditory skills, mobility and generalized body movement. They need social involvement and wide experience so that they can relate what they are reading to their own life. Reading material must be relevant. Use of the Barraga Scale suggests development of visual skills and these have transfer value to other learning situations. Reading materials must be drawn from a wide variety of sources to ensure children learn to handle printed matter other than

in one standard form, e.g. in science it is necessary to handle graphical and illustrative material and technical vocabulary. Skills of skimming, scanning and reviewing must be taught and research into rapid reading is urgently required. The teacher must be taught use of scales and tests which can provide information into visual learning. Finally all avenues of input must be explored and teacher-materials produced.

Tait, P.

A description analysis of the play of young blind children.

Education of the Visually Handicapped, 1972, IV(1), 12-15.

In order to determine whether or not the play of blind children differed from that of sighted peers during a controlled play situation, 29 legally blind children, 4-9 years of age, were presented with special play materials during individual 15-minute free-play sessions. Analysis of the narrative case records indicated that the blind children differed from the seeing children in the following ways: (1) the blind children had an inability to comprehend the space around them or spatial boundaries in general, as shown by their concern with the partitions in the room, the roles assigned by them to a cardboard box, etc.; (2) blind children showed less flexibility in their approach to play materials (e.g., a hat was always used as a hat by blind children, while sighted children used hats as beds, bowls, etc.); (3) blind children asked more questions than sighted children and, in general, attempted to establish contact with the observer more frequently than did the seeing children. The author discusses the role of play in the education of the blind child.

Tait, P.

Play and the intellectual development of blind children.

The New Outlook for the Blind, 1972, 66, 361-369.

Reviews research on the use of play activities for the intellectual development of sighted and blind children. The literature points to the difference in play and its role between sighted and blind children. Blind children lack the desire to play and their play pattern is limited. Form and content of their stories, dreams and play suggest a greater concreteness and lack of flexibility or associational variety. The role of play in the intellectual development of the blind child differs in regard to acquiring knowledge of reality of objects and situations, language and abstract functioning, and of inner life. Since play is a vital element in educational development, educators of blind children may need to foster spontaneous play activities before any meaningful academic learning can be accomplished. The blind child must be taught to engage actively, creatively, and independently in spontaneous play activities.

Talkington, L. W.

An exploratory program for blind-retarded.

Education of the Visually Handicapped, 1972, IV(2), 33-35.

Twelve blind-retarded residents of a public institution for the mentally retarded acted as subjects in an intensive stimulation/activity program designed to increase activity and skill in communication, socialization, sensory stimulation, and mobility. Basic reinforcement techniques were utilized throughout, including use of both food and positive verbal responses (praise and encouragement). Pre- and post-measures, using the Verbal Language Development Scale and the Vineland Social Maturity Scale, revealed a 1.9 year increase in language age and a 1.3 year increase in attainment age by the end of the program.

Thier, H. D.

Laboratory science for the visually handicapped blind child.

The New Outlook for the Blind, 1971, 65, 190-194.

A "Direct Experience" science program is described and two examples are discussed fully. The first is a biological science unit entitled "Organisms." In the direct-experience, laboratory approach of the program, children learn about such concepts as birth, death, reproduction, habitat, by experiences with classroom aquaria and the fish and plants found in them. Blind children are able to discover the characteristics of fish directly by utilizing a special aquarium set-up--a second duplicate plastic aquarium with holes in the bottom, is placed in the first and the water comes through the holes from the first into the second aquarium. The fish is then put into the second aquarium, the blind child tips the second aquarium so that almost all the water runs out and the fish is trapped in the remaining water at the bottom. The blind child can then put his hand in and feel the movement of the fish, its shape, action of fins, etc. It has been found that the child can even lift the fish out of the water to explore it further without damage to the fish. The blind child is given a piece of clay from which to develop his own model of what the fish looks like. Similar explorations can be made with snails, plants, and filamentous algae. "Food-web" concepts are taught by placing guppies in a tank with goldfish. The guppies' subsequent disappearance leads the children to develop hypotheses for the cause of the disappearance and after experimentation they can become aware of the various links in the chain.

A physical science unit on liquid solutions is also described. Blind children are able to determine whether or not a liquid substance is a solution (a mixture which is clear, not cloudy) by the use of filters. Any evidence of a residue left in the filter paper after the liquid is poured through, is an indication that the liquid is a non-solution. A further test is made to determine whether the liquid thus identified as a non-solution might also contain a solution as part (subsystem) of the mixture. This is done by allowing the filtered liquid to evaporate. If the liquid is only water, little or no residue is left. If it is actually a solution, a great deal of residue remains and the blind child can determine that the liquid was also a solution.

Part of the development of the program is the design of evaluation activities. This is as yet uncompleted, but will involve developing tests to determine the intellectual development of visually handicapped children, the success of the adaptations made in the program, and the effectiveness of the program as a whole.

Tillman, M. H.

The factor structure of verbal abilities of blind and sighted children.

Paper read at 1967 AERA Annual Meeting.

The purpose of the present investigation was to describe the performance of blind and sighted children on the Verbal Section of the WISC. Performance was evaluated in terms of factor comparisons between sub-tests using items as variables. Specifically, the emphasis was placed on developmental aspects of performance. Do blind and sighted children of similar age and sex perform equally well on the WISC Verbal sub-tests? Do both groups have comparable factor structures?

Results for each sub-test include test statistics, tetrachoric inter-item correlations, and principle components factors with varimax rotation. The obtained factor structures were quite similar; however, the communalities for the blind on all sub-tests except Arithmetic were low. The application of factor analysis to the tetrachoric inter-item correlations for each of the WISC Verbal sub-tests can most parsimoniously be described by a proximity-difficulty pattern. In terms of educational objectives, there are several conclusions to be made about the blind. First, there appears to

be a lack of integration among educational experiences with the result that each bit of knowledge is isolated and cast into a separate frame of reference. Second, verbal abilities focus on a basic vocabulary without much elaboration. Third, the blind tend to approach abstract conceptualization problems from a concrete and functional level and consequently lag behind the sighted children. And finally, the blind are quite comparable to the sighted in numerical ability.

Tillman, M. H.

The performance of blind and sighted children on the Wechsler Intelligence Scale for Children: Study I.

International Journal for the Education of the Blind, 1967, XVI(3).

The purpose of the present investigation was to describe the performance of blind and sighted children on the WISC. Performance was evaluated in terms of item-difficulty curves, t-tests, and subtest reliabilities. Results indicated that blind children score about the same as sighted children on Arithmetic, Information and Vocabulary, but did less well on Comprehension and Similarities. When IQs were pro-rated from Arithmetic, Information and Vocabulary Scores, the resulting IQ was shown to be higher than an IQ based upon Arithmetic, Information, Vocabulary, Comprehension, and Similarities. The depressing effect produced by Comprehension and Similarities was shown to be offset by a spuriously high Digit Span score. Moreover, if desired, the 6 subtest WISC IQ could be accurately predicted from the 3 subtest IQ based on Arithmetic, Information, and Vocabulary.

Tillman, M. H.

The performance of blind and sighted children on the Wechsler Intelligence Scale for Children: Study II.

International Journal for the Education of the Blind, 1967, XVI(4).

The application of factor-analysis to the tetrachoric inter-item correlations for each of the WISC verbal subtests can be described by a proximity-difficulty pattern. Across groups, the obtained factor structures were similar on Arithmetic, Information, and Comprehension but less so on Similarities and Vocabulary. Fewer factor loadings and weaker communalities for the blind on all subtests except Arithmetic suggest a greater specificity in the organization of abilities sampled by these tests. In terms of educational objectives, there are several conclusions to be drawn about the blind: first, there appears to be a lack of integration among educational experiences with the result that each bit of knowledge is isolated and cast into a separate frame of reference; second, verbal abilities focus on a basic vocabulary without much elaboration; third, the blind tend to approach abstract conceptualization problems from a concrete and functional level and consequently lag behind sighted children. Finally, the blind are quite comparable to the sighted in numerical ability.

Tillman, M. H., & Williams, C.

Word associations of blind and sighted children to selected form classes.

A.E.R.A., 1968.

More than thirty years ago, Payne (1933) studied free associations of blind children to a modified version of the Kent-Rosanoff word list. She reported that blind children gave more idiosyncratic responses, more perseverative responses, and fewer common responses: consequently, Payne suggested that blind children had a restricted field of association. The present investigation, also using word association techniques, was designed to examine levels of syntactic development in blind and sighted children. Since association on the basis of syntactic function, that is, homogeneous or paradigmatic responding, is highly related to the development of syntax in children, word association responses in the present study were scored correct when the response member was the same part of speech as the stimulus word.

Thirty-five blind children, seven at each age level from seven through

eleven years, were obtained from three Southeastern residential schools. A sighted group comparable to the blind in age, intelligence, number, and socio-economic background was obtained from three communities in Georgia. Two tasks were involved: a word association (WA) task (Brown and Berko, 1960) consisting of 36 high-frequency stimulus words from six parts-of-speech categories, count nouns, mass nouns, transitive verbs, intransitive verbs, adjectives, adverbs; a word usage (WU) task consisting of nonsense syllables introduced within a syntactical context such that the six form classes of interest were represented; in the latter task, the child was asked to supply a meaning for the nonsense syllable.

Results (Groups X Level Anova) indicated that on WA tasks both groups scored about the same level, that rate of development was about the same, and that the sequence of development was highly correlated. On WU however, a ceiling effect was obtained for the blind group but not for the sighted group. Several possible explanations were considered: biased low estimate of the intelligence of the blind group; effects of heterogeneity of variance; a possible confounding of subject and task variables; and a face-value hypothesis. It was suggested that the use of younger children would clarify the nature of differences obtained in the WU task. In short, while it is possible to infer specific language deficiencies based on research literature, the results provided no support for a developmental lag in the blind group's acquisition of syntax.

Tobin, M. J.

Conservation of substance in the blind and partially sighted.

British Journal of Educational Psychology, 1972, 42, Part 2, 192-197.

Previous investigations of the effects of visual impairment on the development of perceptual and cognitive skills are discussed and related to the practice of making separate educational provision for the visually handicapped. The alleged developmental lag is examined from a different viewpoint, and, on the basis of a conservation of substance experiment with 189 blind and partially-sighted children, it is inferred that while the best of them are performing on a par with the best of their sighted peers, the age range in which conservation is attained is more extended for the visually handicapped. It is suggested that Piagetian-type tasks may be of direct practical use to teachers for diagnostic and teaching purposes.

Tuttle, Dean W.

A comparison of three reading media for the blind.

Education of the Visually Handicapped, 1972, IV(2), 40-44.

One hundred four subjects took three equivalent forms of the Reading Versatility Test, intermediate level--one in braille, one in normal reading, and the third in compressed speech. Comprehension scores, both of braille and normal recording, revealed 4 levels: (1) low braille readers, high listeners; (2) high braille readers, low listeners; (3) low braille readers, high listeners; (4) low braille readers, low listeners. Analysis of variance over the four levels and overall indicated the following conclusions: (a) for total sample, no difference in comprehension among the three media; (b) for the total sample, reading by braille took twice as long as by listening to recording, and almost three times as long as by compressed speech; (c) for the total sample, reading by listening to compressed speech was more efficient than reading by listening to normal recording which, in turn, was more efficient than reading by braille.

Umsted, R. G.

Improving braille reading.

The New Outlook for the Blind, 1972, 66, 169-177.

In order to determine whether instruction for increasing the speed and accuracy of the recognition of one-cell whole word and part-word signs,

the two-cell contractions, and the short-form words in English braille would improve the braille reading process, 72 high school students were divided into high, medium and low levels of reading by scores on a silent reading test. Thirty-six of the students received a special 15-day training program, 1/2 hour per day, on the braille code; the control group of 36 subjects received no special training. Pre- and post-training scores were obtained on time and accuracy for braille code recognition and for oral reading; pre- and post-training scores for time and comprehension on silent reading tests were also obtained, under motivated conditions (a monetary reward being given for greatest improvement). Results showed that statistically significant differences were found on post-tests in favor of the experimental group in accuracy and speed on the braille code recognition test, and on the rate of silent reading. The high reading level subjects of the experimental group also showed statistically significant improvement in rate on the oral reading measure. Results of this study indicate that braille reading can be improved by extra training in braille code recognition. Educational implications are discussed.

Vopata, A.

Making mobility meaningful.

The New Outlook for the Blind, 1973, 67, 161-167.

The sequential orientation and mobility curriculum in use at the Iowa Braille and Sight Saving School consists of 127 lessons divided into 5 units of instruction (indoor travel, campus travel, residential travel, basic business travel and advanced business travel). In addition to the motivational possibilities built into the curriculum, the instructional staff have also experimented with a mobility quiz contest and with awards and cash prizes for achievement and extra-curricular travel experience. The specific skills and tasks involved in each unit are listed.

Wachs, T. D.

Personality testing of the handicapped: A review.

Journal of Projective Techniques & Personality Assessment, 1966, 30(4), 339-355.

The author reviews the validity and utility of various projective and non-projective tests with handicapped populations. Five types of handicapping conditions are considered: blindness, deafness, speech disorders, motor disorders and intellectual retardation. The utility of varied tests for personality diagnosis in these areas is indicated either by evaluation of research on the tests or by noting special features of specific tests which may be useful in diagnosis even though no research has yet appeared. A summary is included after the discussion of each handicapping condition indicating which tests seem most promising.

The author's summary of personality testing for the blind suggests that one of the adaptations of the MMPI would appear to be the most applicable for use with the visually handicapped. It is noted that with the exception of various teacher rating scales (still in developmental stage) there appear to be no other applicable non-projective tests for the blind. In considering projective techniques, while several promising measures are noted (AAT, Sound Test and Verbal TAT), it is concluded that there is no one major test upon which the clinician can rely. It is suggested that best results would be obtained from use of a battery of tests consisting of the Rotter ISB, the Insight Test, and the MMPI.

Weiner, L. D.

The performance of good and poor braille readers on certain tests involving tactual perception.

International Journal for the Education of the Blind, 1963, XII(3), 72-77.

Two groups of 25 children given 6 experimental tests of tactual perception. Three tests were simple in form; 3 required complex tactual preparation. The 2 groups divided into

good and poor braille readers--Group I and Group II. Both groups performed similarly on the simple tactual perception tests but Group I performed significantly better on the complex tests. No definitive relationships found between tests and the variables of mental age, chronological age, IQ's, and reading achievement. Concluded that other factors might be related to tactual perception, e.g. increased neural sensitivity in fingertips of good readers, high development of gross and/or fine motor coordination, and possession of this skill in isolation of influencing factors.

Weininger, O., Rotenberg, H., & Henry, A.

Body image of handicapped children.

Journal of Personality Assessment, 1972, 36, 248-253.

In an investigation of the body image of handicapped children, eight institutionalized children with spina bifida were compared with eight similarly afflicted children residing at home and attending a special day-school for handicapped children. A control group of eight normal children were matched for age and sex, as were the two handicapped groups. All subjects were within the normal range of intelligence. A make-a-person task was individually administered. The three-dimensional figures created by the subjects were duplicated in exact proportion on graph paper to facilitate measurement and to obtain pertinent data. Results indicate that the institutionalized group has a more distorted body image than that of either the group attending day-school or the normal group.

Weinlader, H.

"Attitude" as a basic concept in social psychology of the visually handicapped.

The Visually Handicapped, 1972, 1, 93.

As human behavior is always borne and molded by social factors, this article begins with pointing out the importance of social psychology for the interpretation of human interaction in general and for the understanding of personal and world experience of visually handicapped persons in particular. After a short discussion of the concept of "attitude" and the methodological limitations of research concerning attitudes in this special field, several studies dealing with attitudes towards the visually handicapped are reported. This report is arranged in four fields of problems: A, studies concerning the determination of attitudes of the seeing public towards the blind give only few indications of difference or negative attitudes. The dependence of results from research methods was already pointed out; B, some studies concerning the attitudes of persons having daily intercourse with visually handicapped people could state a wide spread of opinions; C, based on studies of Sommers, Cowen and others the attitudes of parents of blind children are reported, and mechanisms are shown, which parents apply to be able to put up with the lot of having a blind child. The importance of parental attitudes for the behavior and self-concept of the child is accentuated; D, by the example of the two personal testimonies the inconsistency of attitudes towards blindness among the blind themselves is illustrated. Inconsistency and uncertainty in front of one's own position could be found by several studies. Finally two theoretical concepts which are frequently met in literature are briefly described and discussed. They are arranged within a more general model developed by Allport.

Williams, M.

Braille reading.

The Teacher of the Blind, 1971, LIX(3), 103-116.

"Over 600 Ss, aged 10 to 18 years, were given the Ballard Silent Reading Test, transcribed into braille. It was found that about 40 percent of those from 10-16 years were unable to complete the test satisfactorily. Several factors were suggested as responsible; it is likely that additional physical or mental handicap to blindness accounted for a large

proportion, while the position was aggravated by factors such as late admission to blind school, absences from school, a negative attitude towards the learning of braille, etc. For the 60 percent who completed the test a reading rate of about 100 words per minute was found to be average. Two small groups of sighted children, of 11 and 14 years of age, were given the same reading and completion test. It was found that when blind Ss of comparative ages had mastered the mechanics of braille reading, their ability to comprehend the test narrative was equal to that of their sighted peers, but that their reading rate was only about half as fast."

Winkley, W.

Public high school or residential high school for blind students?

Education of the Visually Handicapped, 1972, IV(4), 120-121.

Subjects--28 college students who spent last 3 years of high school in a residential school. Ninety-five college students who spent last 3 years of high school in a public school. All legally blind. Questionnaires were sent out to rehabilitation counselors to find out whether there was any demonstrable difference in academic success at college between the 2 groups. Results showed that both residential and public schools were doing equally well in preparing students for academic work in college. The samples were found to be very much alike in variance, too. Conclusion--the Study suggests that residential/public schools equally good on academic side, now need additional research in the areas of social competence and social adjustment.

Yamprey, N.

Problem of the defective child.

Psychological Abstracts, 1964, 38, Item 3007.

"Every defect, whether physical or functional, major or minor, has an effect on the family nucleus which has a further effect on the child's development. The disturbance is motivated by frustration, generating hostility and guilt. These emotions distort communication and learning and threaten family happiness. Correction of the problem must deal with the entire disturbed constellation."

Zahran, H. A. S.

A study of personality differences between blind and sighted children.

British Journal of Educational Psychology, 1965, 35(3), 329-337.

In the literature there are two different points of view regarding the possible personality differences between the blind and the sighted. The first considers that blindness leads to compensatory behavior, possibly accompanied by personality maladjustment and introversion. The second implies that in regard to basic personality variables, the process of adjustment in blind persons is not significantly different from that of the sighted.

The writer carried out an experiment with matched groups of blind and sighted children to offer quantitative data on this problem. The Williams' Intelligence Test for Children with Defective Vision was used for assessing the IQ's. For personality assessment, the writer prepared a Blind Children's Structured Interview, a Sentences Completion Test and a Semantic Differential. The Junior Maudsley Personality Inventory was also used.

After a pilot study and administration of the tests, the data were analyzed and almost all the test results agreed with each other in giving statistically non-significant differences in favor of the sighted, thus supporting the second point of view.

Zweibelson, I., & Barg, C. F.

Concept development in blind children.

The New Outlook for the Blind, 1967, 61, 218-222.

Two groups of 8 subjects each, one blind, the other sighted, well matched in terms of age, sex, intelligence, and socioeconomic background, had their responses to each word in the similarities and Vocabulary subtests of the WISC rated on the basis of whether it was a concrete, functional, or abstract definition. The results indicated a difference between the 8 matched pairs of subjects which was significant at the 0.05 level, the blind subjects choosing primarily concrete and functional responses, and the sighted subjects choosing more abstract responses. This supported the prediction that blind children would not use abstract concepts to the extent of children with normal vision. In view of the findings of this and of several other studies, the experimentors suggest that the educational techniques used in teaching the blind should be reevaluated and modified to take into account the blind child's deficiencies in abstract concept formation, especially in the integrated school situation.

ABBREVIATIONS OF ORGANIZATIONS

Editor's Note. Several of our readers have indicated confusion about the use of abbreviated names of organizations in manuscripts published both in the *Research Bulletin* and in certain other publications. Authors may also quite naturally use abbreviations of organizations within their own countries without realizing that not all readers will share this common core of knowledge.

We shall try to alleviate this problem by publishing the following compendium of abbreviations for organizations we have come across in our own materials.

Additions and corrections will be welcomed.

Asterisk indicates that publications are also available from:

Superintendent of Documents
U.S. Government Printing Office
Washington, D.C. 20402.

AAIB American Association of Instructors of the Blind

now known as:

AEVH Association for Education of the Visually Handicapped
1604 Spruce Street
Philadelphia, Pennsylvania 19103, U.S.A.

AAWB American Association of Workers for the Blind
1511 K Street NW,
Washington, D.C. 20005

ABAPSTAS Association of Blind and Partially Sighted Teachers and Students
T. Moody (Secretary),
Department of Political Economy,
University of Glasgow,
Glasgow, G12 8RT, Scotland.

ACB American Council of the Blind
106 N.E. Second Street
Oklahoma City, Oklahoma 73104

ACM Association for Computing Machinery
ACM Committee on Professional Activities of the Blind,
The Mitre Corporation,
433 North Circle Drive,
Colorado Springs, Colorado 80206

AFB American Foundation for the Blind
15 West 16 Street,
New York, New York 10011

works in cooperation with

AFOB American Foundation for Overseas Blind
22 West 17 Street
New York, New York 10011

AFIPS American Federati of Information Processing Societies
211 East 43rd Street,
New York, New York 10017

AOA Administration on Aging
U.S. Department of Health, Education, and Welfare,
330 Independence Avenue, SW,
Washington, D.C., U.S.A.

APH American Printing House for the Blind
1839 Frankfort Avenue,
Louisville, Kentucky 40206

BCAB British Computer Association of the Blind
BCAB, BCM, Box 950,
London, WC2, England

CCD Central Council for the Disabled
34 Eccleston Square,
London, SW1V 1PE, England

CEC The Council for Exceptional Children
1411 South Jefferson Davis Highway,
Arlington, Virginia 22202

CIE Centre International de l'Enfance
Chateau de Longchamp,
Bois de Boulogne,
Paris 16^{e}, France

*DBPH Division for the Blind and Physically Handicapped
U.S. Library of Congress,
1st Street and Independence Avenue, SE,
Washington, D.C. 20540

DES Department of Education and Science,
Elizabeth House, York Road,
London, SE1 7PH, England

DHSS Department of Health and Social Service
Alexander Fleming House,
Elephant and Castle,
London, SE1 6BY, England

DIG Disablement Income Group
Queens House,
180-182 Tottenham Court Road,
London, W1P OBD, England

*ERIC Educational Resources Information Center
U.S. Department of Health, Education, and Welfare,
Office of Education,
400 Maryland Avenue, SW,
Washington, D.C. 20202

GIHP Groupement des Intellectuels Handicapes Physiques
8, allee des Myosotis, 8
54500 Vandoeuvre, France

*HEW U.S. Department of Health, Education, and Welfare
330 Independence Avenue, SW
Washington, D.C. 20202

HMSO Her Majesty's Stationery Office
London, England

IBSH Institut fur Blinden- und Sehbehindertenpadagogik
6804 Ilvesheim/Heidelberg
Schlossstr. 23
West Germany

ICEBY International Council for the Education of Blind Youth

now known as:

ICEVH International Council for the Education of the Visually Handicapped
Perkins School for the Blind
175 North Beacon Street
Watertown, Massachusetts 02172

ICTA ISRD Committee on Technical Aids
Housing and Transportation
Fack
S-161 03 Bromma 3
Sweden

IEE Institution of Electrical Engineers
Savoy Place
London WC2R OBL, England

IEEE Institute of Electrical and Electronics Engineers
345 East 47th Street
New York, New York 10017

ILO International Labour Office
CH 1211 Geneva 22
Switzerland

IRCS International Research Communications System
U.K.: P.O. Box 500
St. Leonard's House
Lancaster, England

and:

University Park Press
Chamber of Commerce Building,
Baltimore, Maryland 21202, U.S.A.

IRIS International Research Information Service
American Foundation for the Blind
15 West 16th Street
New York, New York 10011

ISRD International Society for the Rehabilitation of the Disabled
219 East 44th Street
New York, New York 10017

MIT Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, Massachusetts 02139

*NAE U.S. National Academy of Engineering
2101 Constitution Avenue, NW
Washington, D.C. 20418, U.S.A.

*NAS U.S. National Academy of Science
2101 Constitution Avenue, NW
Washington, D.C. 20418, U.S.A.

NBA National Braille Association
85 Godwin Avenue
Midland Park, New Jersey 07432

*NEI National Eye Institute
U.S. National Institutes of Health
900 Rockville Pike
Bethesda, Maryland 20014

NFB National Federation of the Blind
Randolph Hotel Building
Des Moines, Iowa 50309, U.S.A.

*NIH U.S. National Institutes of Health
9000 Rockville Pike
Bethesda, Maryland 20014, U.S.A.

*NINDS National Institute of Neurological Diseases and Stroke
U.S. National Institutes of Health
9000 Rockville Pike
Bethesda, Maryland 20014

NRA National Rehabilitation Association
1522 K Street, NW
Washington, D.C. 20005

*NSF U.S. National Science Foundation
1800 G Street, NW
Washington, D.C. 20006

NSPB National Society for the Prevention of Blindness
79 Madison Avenue
New York, New York 10016

*OEBEH Office of Education Bureau for Education of the Handicapped
U.S. Department of Health, Education, and Welfare
Office of Education
400 Maryland Avenue, SW
Washington, D.C. 20202, U.S.A.

RCEVH Research Centre for the Education of the Visually Handicapped
50 Wellington Road
Edgbaston, Birmingham, B15 2EP, England

RCSB Royal Commonwealth Society for the Blind
46 Victoria Street
London, S.W. 1, England

RFB Recordings for the Blind
215 East 58th Street
New York, New York 10022

RNIB Royal National Institute for the Blind
224 Great Portland Street
London W.1, England

SAEDC Sensory Aids Evaluation and Development Center
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, Massachusetts 02139, U.S.A.

SIGCAPH Special Interest Group on Computers and the Physically Handicapped
Association for Computing Machinery
The Mitre Corporation
433 North Circle Drive
Colorado Springs, Colorado 80206

*SRS Social and Rehabilitation Service
U.S. Department of Health, Education, and Welfare
Washington, D.C. 20201

TNO Nederlandsche Centrale Organisatie TNO (Central Organization for Applied Scientific Research in the Netherlands TNO)
The Hague
P.O. Box 297
Juliana van Stelberglaan 148
The Netherlands

*VA Veterans Administration
U.S. Government
Washington, D.C. 20420

VIDPI Visually Impaired Data Processors, International
P. Bryne (Secretary)
1130 S. Michigan, Apt. 716
Chicago, Illinois 60605, U.S.A.

VOS All Russia Society for the Blind
Novaja Plostchad 14
Moscow, U.S.S.R.

WCWB World Council for the Welfare of the Blind
14 Rue Daru
Paris 8, France

WHO World Health Organization
The United Nations
Secretariat Building
833 United Nations Plaza
New York 10017, U.S.A. and:
Palais des Nations
Geneva, Switzerland

Name: AmBiChron Pitch Changer

Source: Richard F. Koch, Consultant
67 Smith Street, Lynbrook, New York 11563

Availability: In serial production.

The AmBiChron is an electronic analog of the rotary-head pitch changer. It divides the incoming signal into segments. Then, it discards or repeats part of each segment, and splices together what is retained. To lower pitch, it discards and stretches the remnant, thereby increasing wavelength. To raise pitch it repeats so that the output signal is--so to speak--squeezed in time, thereby decreasing wavelength. In either case, no gaps or spurious signals are generated. The AmBiChron is all electronic, and uses all off-the-shelf components which are available from a multiplicity of sources. (U.S. Patent 3,816,664, foreign patents pending.)

Name: Audible Digital Electrical Test Meter

Source: Audio Perception
212 Professional Building
150 North Center Street
Reno, Nevada 89501

Availability: 60 days after order.

A digital multimeter for electrical testing by nonsighted persons: results appear both in lighted digits and audible tones corresponding to the reading on the lighted digits. An alternate feature is the availability of a voice reading to correspond to the digits as well as, or in place of, the tones. The meter allows hands-off operation and continuous reporting of variations in the readings being obtained.

Name: Audible Electronic Calculator

Source: Audio Perception
212 Professional Building
150 North Center Street
Reno, Nevada 89501

Availability: 60 days after order.

An audible electronic calculator, which can be operated by nonsighted persons: the results appear in lighted digit form; and in audible tones corresponding to the lighted digits. An alternate feature is the availability of a voice reading to correspond to the digits as they are lighted.

Standard model available in normal functions together with memory. Upon special order virtually all calculator functions can be included.

Name: Audible Multi-meter

Source: G. P. Roberts
10A Mason Avenue,
Cheltenham 2119,
N.S.W., Australia

Availability: One off model. Instructions for building further instruments can be obtained from Mr. Roberts.

The instrument is battery powered and completely self-contained. The front panel contains a pair of input terminals, a row of six pushbuttons for range selection and the read-out potentiometer. In use, the input terminals are connected to the circuit under test, a suitable range of voltage or current is selected and the read-out knob is slowly rotated until the point is found at which the whistle from an internal oscillator ceases. The read-out knob is fitted with a pointer approximately 2 in. long, the position of which can be readily felt in relation to an embossed scale marked in braille from 0 to 10. It is found that with little practice, blind students can thus obtain measurements with a degree of accuracy comparable to that of a conventional moving-coil meter.

Name: Automotive Electronic Engine Timing Instrument

Source: American Foundation for the Blind, Inc.
15 West 16th Street
New York, New York 10011

Availability: Laboratory prototype

The instrument uses a pressure transducer or gauge, in place of one of the spark plugs. The transducer electrically transmits cylinder pressure information, which is electronically converted into a "top dead center" position of the piston travel. This computed piston position is compared to the spark plug firing from the distributor.

A brailled multiposition switch which can be set to conform to the car manufacturer's timing specification is used to set the engine timing by turning the switch to the specified number of degrees before or after "top dead center." The mechanic has an audible or tactile indicator from which he adjusts the distributor for a null.

Name: Digital Volt-Ohmmeter for the Blind

Source: T. C. R. S. Fowler, B.Sc.
University of Bristol,
H. H. Wills Physics Laboratory,
Royal Fort, Tyndall Avenue,
Bristol, BS8 1TL, England.

Availability: Experimental prototype.

Significant features of this instrument are the use of 12 rocker switches arranged in three groups of four to give 3-decade voltage settings and readout (a 4, 2, 2, 1 weighting code is used), a spring-loaded bar switch to add one further least significant digit when pressed, and a high/low frequency audible output controlled by a voltage comparator. Two rotary switches and a multiplier lead enable one of seven dc voltage ranges or five resistance ranges to be selected. Total component cost is about £15 (U.S. $36).

In operation, after a suitable range has been selected (by experiment if necessary), the measurement is made by switching all rocker switches to the

"off" state (left hand side down), and then switching them on in sequence, starting with the most significant digit, each switch being left on if it does not cause the audible tone to change, but switched off if it causes a (high-to-low) change in the output frequency. When the process is complete pressing the bar switch will cause the tone to change. The states of the twelve rocker switches are then sensed by touch giving a reading in 3-digit decimal form. The measurement typically takes about 20 seconds.

The readout requires no extra encoding, and is readily used by sighted people and blind people with no knowledge of braille. The blind man for whom the instrument was developed has commented enthusiastically on the ease of use and unprecedented accuracy which it makes available to him. It would appear worthwhile to develop, for production, a complete digital multimeter on similar lines.

Name: Electromechanical Braille Line

Source: Arbeitsgemeinschaft fur Rehabilitationstechnik e.V. an der Universitat Stuttgart
D-7000 Stuttgart 1,
Schloss Solitude, Haus 3
West Germany

and

Institut fur Konstruktion und Fertigung in der Feinwerktechnik (FWT)
(Institute for Construction and Production of Miniature Device)
Universitat Stuttgart

Availability: Preproduction prototype.

ART and FWT have developed a braille line that is an improvement in braille reproduction. The device takes electrical signals in any form whatever; and produces tactile braille symbols without paper.

The braille symbols are produced by movable pins arranged in a braille matrix of standard dimensions. The pins can be lowered to erase the line and then raised to form a new line. The pins are held stationary while being read. An advantage of this system is that large quantities of information can be presented tactually without expendables (for example reading of books via a reading machine or video-display computer or telecommunication terminal).

The device is a modular display, the module being a six-dot braille cell such that braille lines of any desired length can be made.

<u>Technical Data</u>

Module width (intra cell)	7.3 mm. (0.287 in.)
Pin spacing (inter cell)	3.0 mm. (0.118 in.)
Pin diameter	1.5 mm. (0.059 in.) spherical
Writing Rate	30 characters-per-sec.

<u>Applications</u>

Reading Machine
Electronic Calculator Display
Braille terminal (e.g. teletype)
Digital display for measuring instruments
Instructional system for teacher-students
Instructional system for programmers

and many others

Name: Electromechanical Numeric Braille Display

Source: George F. Dalrymple, Acting Director, Sensory Aids Evaluation and Development Center Massachusetts Institute of Technology

Availability: Pre-production prototypes and a one-off working unit.

The device can be interfaced with almost any electronic instrument with digital binary coded decimal (BCD) outputs. Several variations on the basic design have been developed for use with various electronic equipment. The concept can be extended to modules that display the full braille cell, providing a complete alphanumeric display.

Name: Environmental Sensory System with Audio Output

Source: Richard G. Beschle, Associate Professor of Life Sciences, Worcester Polytechnic Institute, Worcester, Massachusetts

Availability: Laboratory prototype.

The system scans objects with a Robot Research Model 80 TV camera coded for edge detection (tone sounds only when a change from light to dark or vice-versa is encountered). The camera feeds into a number of hard-wired circuits, which provide a tone to either of two headphones. A voltage-variable oscillator generates the tone and the voltage in the TV oscillator determines the pitch. Frequency of sound indicates position along vertical, higher frequency for higher position, lower for lower position. Variation in amplitude of sound delivered to each ear indicates position along the horizontal. Subjects have been able to identify household objects with the device.

Name: Liquid Level Detector

Source: General Electric Research and Development Center, Schenectady, New York

Availability: Production prototype.

Battery-operated electronic device to detect the level of liquid in a cup or glass. When liquid rises up to the two sensors by which the device is suspended, (about 1/2 in. from the rim), the sensors begin to act as electrodes transmitting current through the liquid. A buzz is then emitted by the device.

Name: Man-Machine Tactile Communication Device

Source: Dr. A. Michael Noll,
Bell Telephone Laboratories, Inc.,
Murray Hill, New Jersey

Availability: Laboratory prototype

The device presents the user with three-dimensional tactual-kinesthetic sensory input. The user experiences the shape of the object programmed for display through the device by means of a hand-held movable ball fixed to a shaft. The position of the ball is monitored by means of three potentiometers. The force required to move the ball in any direction is controlled by three motors. Each pair of motors and potentiometers thus controls movement along one axis of three dimensional space. For the user the effect of moving the hand-held ball is that of exploring the shape of the programmed object tactually, using the ball as a probe. FORTRAN-compatible software has been written for controlling the motors in the device. Other programs have been written to simulate objects and surfaces.

Name: Paper Currency Identification Device (Revised listing)

Source: Southwest Research Institute
8500 Culebra Road
San Antonio, Texas 78284

Availability: The device is now being manufactured under the name "Paper Money Identifier" by Marchak Engineering and Manufacturing Co., Austin, Texas, and distributed by Applied Rehabilitation Systems, 3902 Idlewild, Austin, Texas. It is also manufactured by Delta Meter Service, 1717 West 9th Street, Los Angeles, California 90015.

Name: Spellex Talking Typewriter

Sources: Dr. Michael P. Beddoes
Department of Electrical Engineering
Vancouver 8, B.C., Canada

or

Dr. Ching Y. Suen
Department of Computer Science
Sir George Williams University
Montreal, P.Q., Canada H3G 1M8

Availability: Experimental Prototype.

A digital instrument which gives the spoken sound of the character each time a key of the electric typewriter is pressed. Designed for both beginner and professional typists, it includes an editor for correcting typing errors. Available for demonstration in Vancouver and Montreal.

Name: Spelltalk (Audio output for reading alphanumeric.)

Source: R. L. Longini,
Medical Systems Engineering Laboratory,
Carnegie-Mellon University,
Pittsburgh, Pennsylvania 15213, USA

Availability: Laboratory prototype (fourth generation device built)

Electronically produced output is triggered by character recognizer or by machine readable record. Sounds are voice like enough so that 100 percent phonetic output can be learned as a dialect. Forty hours of training (high IQ) permits 150 words-per-minute of English to be understood. Price is estimated at about $300 with suitable input if built in quantity.

Name: Tactile Digital Readout (Revised listing)

Source: American Foundation for the Blind
15 West 16th Street,
New York, New York 10011

Availability: Experimental prototype.

The earlier "Digi Tac" and "Digital Voltmeter" prototype has been superseded by a version which provides a braille display instead of a binary coded tactile readout. The present version uses a four-dot solenoid matrix with electrical encoding. The encoding is done using a "read only" memory from a standard seven segment display device and converting the numbers to braille. A working prototype has been completed using a single braille cell with electronic "digit" switching so that the numbers are read sequentially. A model using 8 or 12 braille cells for an in-line display is under development. The main thrust for this project has been towards providing an electronic calculator readout. The next phase will be to apply these circuits to various digital display instruments.

Name: Talking Desk Calculator for the Blind

Source: Priv.-Doz. Dr. H. Bebie
Institut fur theoretische Physik der Universitat,
Sidlerstrasse 5
CH-3000 Bern
Schweiz

and

Prof. Dr. F. Fankhauser
Univ.-Augenklinik
Inselspital
CH-3008 Bern
Schweiz

Availability: Production prototype. Manufacture and distribution by INTERZEAG AG, CH-8953 Dietikon, Switzerland, scheduled for 1975.

Spoken output is in words from zero to nine with a buzzer to indicate the decimal point. A starting button has been added to the regular calculator keyboard to initiate the spoken output. Output can be elicited repeatedly. Also figures typed into the calculator can be elicited by means of the same button, for verification before the calculating process begins.

Name: Three-channel vibrotactile speech-reception aid for the deaf

Source: James D. Miller,
Central Institute for the Deaf,
St. Louis, Missouri 63110

Availability: Laboratory prototype.

Envelopes of signals from (1) an accelerometer attached to the talker's nose, (2) a microphone near his mouth, and (3) an accelerometer attached to his throat have been multiplied by a 100-Hz square wave and the products used to drive three vibrators. The vibrators have been placed on separate fingers of one hand, or on a single finger.

Name: Transcriptor

Source: Arbeitsgemeinschaft fur Rehabilitationstechnik e.V. an der Universitat Stuttgart
D-7000 Stuttgart 1,
Schloss Solitude, Haus 3
West Germany

and

Institut fur Konstruktion und Fertigung in der Feinwerktechnik (FWT)
(Institute for Construction and Production of Miniature Device.)
Universitat Stuttgart

Availability: Laboratory prototype.

A laboratory model to demonstrate the functions of an inexpensive portable reading machine for the blind.

The Transcriptor developed at the ART and FWT of the University of Stuttgart represents the first step in the development of reading machine for the blind that can be used equally at work or at home. It has shown the feasibility of building a portable reading machine using a serial optical correlator (OCR).

The characters are scanned by a movable reading head with mask. The characters are compared, correlated and recognized. The recognized signs are transformed into braille and embossed on a strip of paper.

Present State of Development

Type Faces:	Courier (IBM)	29 upper case letters on.
	Helvetica	26 upper case letters
Reading Speed:	6 characters per second	
Error Rate:	3 percent	

Present State of Development (continued)

Line Feed:	Manual
Page Size:	DIN A4

Development Goals

The goal is to develop a reading device about the size of a portable electric typewriter.

Type Faces:	Recognize all normally used letters, both upper and lower cases, numbers, and special signs.
Reading Speed:	15 characters/sec.
Error Rate:	0.5 percent
Page Size:	Din A4

Automatic focusing and magnification.

Automatic line positioning and following.

Output:	Braille line display Braille strip printer Braille page printer Magnetic tape or spoken word, depending on application, form desired and available equipment.
Development time:	Estimated 2 years.

Name:	Transicon (Revised listing)
Source:	The Scientific Research Foundation Jerusalem, P.O.B. 375 Israel
Availability:	First commercial model is now available under the name "TEXTOBRAIL" from the Israel Electro-Optical Industry, Ltd., P.O.B. 1165, Rehovot 76110, Israel.

PUBLICATIONS OF NOTE

American Printing House for the Blind. Educational research, development, and reference group: Report on research and development activities--Fiscal 1974. Louisville, Ky.: American Printing House for the Blind, 1974. (unpublished report)

Aposkitis, C. Le role des oligo-elements dans l'apparition de la cataracte senile. *Ana. Oculist*, (Paris), 1970, 10, 925-930.

Aranda, R. R. *CILS: A model for the social rehabilitation of older persons with severe visual impairment.* New York: Center for Independent Living, New York Infirmary, March 1974, 50 pp.

Ball, T. S., McCrady, R. E., & Hart, A. D. Automated reinforcement of head posture in a cerebral palsied retardate. *Perceptual & Motor Skills*, 1974, in press.

Beddoes, M. P. Experimental study of the Spellex editing talking typewriter. In *Proceedings of the 1973 International Conference on Cybernetics and Society.* (Boston, Massachusetts, November 5-7, 1973) IEEE Systems, Man and Cybernetics Society, 290-291.

Beddoes, M. P., Suen, C. Y., Dixon, B. A., & George, R. G. Spellex: An automatic talking typewriter for the blind. In Digest of the 10th International Conference on Medical and Biological Engineering, Dresden, 1973, 121.

Berkowitz, M., Englander, V., Rubin, J., & Worrall, J. D. *An evaluation of rehabilitation research.* New Brunswick, N.J.: Disability and Health Economics Research, Bureau of Economic Research, Rutgers University, August 1974. 315 pp. (Report to the National Science Foundation, Washington, D.C., Research Applied in National Needs, 73-7, Research Grant No. GI-39420, Proposal No. P312625)

Berla, E., & Murr, M. J. Searching tactual space. *Education of the Visually Handicapped*, May 1974, 6(2), 49-58.

A tactile pseudomap was designed and tested with 144 braille readers enrolled in schools for the blind. Sixteen subjects from each of grades 4 through 12 participated. The pseudomap used point, line, and textured areal symbols.

Bliss, James C. Summary of three optacon-related cutaneous experiments in F. A. Geldard (Ed.), *Conference on vibrotactile communication*, Austin, Texas: The Psychonomic Society, 1974, 84-94.

Bliss, J. C., & Moore, M. W. The Optacon reading system. *Education of the Visually Handicapped*, December 1974, 6(4), 98-102.

Brothers, R. J., & Huff, R. *Manual of suggested activities for the development of sound localization skills.* Louisville, Ky.: IMRC for Visually Handicapped Children, American Printing House for the Blind, August 1972. 17 pp.

Cox, C. H., Blesser, B. A., & Eden, M. A letter structure grammar, with applications to multifont character recognition. *Quarterly Progress Report* No. 114, Research Laboratory of Electronics, MIT, 233-241.

Craig, J. C. Pictorial and abstract cutaneous displays. In F. A. Geldard (Ed.), *Conference on vibrotactile communication.* Austin,

Texas: The Psychonomic Society, 1974, 78-83.

Curtis, W. S., Donlon, E. T., & Tweedie, D. Communicative behavior of deaf-blind children. *Education of the Visually Handicapped*, December 1974, 6(4), 114-118.

Czeslaw, Luszczynski, Mieczyslaw, Suwinski. Zatrudnienie niewidomych w pracy umyslowej (Employment of the blind as white-collar workers), Zakland Wydawnictw crs Warszawa, 1972.

Daugherty, K. M. Listening skills: A review of the literature. *The New Outlook*, October 1974, 68(8), 363-369.

Erber, N. P. Visual perception of speech by deaf children: Recent developments and continuing needs. *Journal of Speech and Hearing Disorders*, May 1974, 39, 178-185.

Flanagan, J. L., & Rabiner, L. R. (Eds.). Speech synthesis. *The Journal of the Acoustical Society of America*, April 1974, 55, 900.

Fonda, G. Evaluation of contact lenses for central vision in high myopia. *British Journal of Ophthalmology*, February 1974, 58(2), 141-147.

Fonda, G., & Thomas, H. Correction of low visual acuity in achromatopsia. *Archives of Ophthalmology*, January 1974, 91, 20-23.

Food and Drug Administration, Department of HEW. Laser products: Proposed performance standard. *Federal Register*, September 4, 1974, 39(172), 32094-32109.

Freiberger, H. (Ed.). Sensory aids. *Bulletin of Prosthetics Research*, BPR 10-20, Fall 1973, 347-364.

Freiberger, H. Mobility. Presented at the Seventy-Eighth Annual Meeting of the American Academy of Ophthalmology, Dallas, September 16-20, 1973. *Transactions of the American Academy of Ophthalmology and Otolaryngology*, Sept./Oct. 1974, 78, 713-721.

Fund, M. M., & Miller, P. L. Locally organized parser for spoken input. *Quarterly Progress Report*, No. 113. Cambridge, Mass.: MIT Research Laboratory of Electronics, April 1974, 163-167.

Geldard, F. (Ed.) *Cutaneous communication systems and devices.* (Conference in Monterey, California, April 17-18, 1973) Austin, Texas: The Psychonomic Society, Inc., 1973. 112 pp.

Genensky, S. M. *Closed circuit TV and the education of the partially sighted.* Santa Monica, California: Rand Corporation, March 1970.

Genensky, S. M., Petersen, H. E., Clewett, R. W., & Moshin, H. L. *A double X-Y platform for Rand-sight-type instruments.* Santa Monica, Calif.: Rand Corp., December, 1974. 43 pp.

This report describes a mechanical platform called a double X-Y Platform. When this platform replaces a single X-Y Platform as part of a closed circuit TV system for the partially sighted, it permits a user to read printed or handwritten material and to take notes on or copy from that material using a pen or pencil. The platform has two rectangular working surfaces whose motions in the left or right direction (x-direction) are completely coupled, but whose motions toward or away from the user (y-direction) are completely independent of one another. This design feature allows the user to change from reading (writing) to writing (reading) without having to search for the line that he was last writing (reading).

Other techniques for handling this important visual information transfer problem have been explored and are also described in this report. However, they do not appear to be as cost-effective as the double X-Y Platform.

A series of experiments was performed with the cooperation of four partially sighted people who differed in age and ocular pathology. These experiments were an attempt to determine whether copying from unbound and bound materials using a CCTV system equipped with a double X-Y Platform can be expected to be more rapid than copying from similar materials using a CCTV system equipped with a single X-Y Platform, or

using neither an X-Y Platform nor a CCTV system. The results of these experiments were not conclusive. However, three of the four subjects reported that they could copy more easily with a CCTV system equipped with a double X-Y Platform than they could using either of the other two techniques.

Genensky, S. M., Petersen, H. E., Yoshimura, R. I., von der Lieth, J. B., Clewett, R. W., & Moshin, H. L. Interactive classroom TV system for the handicapped. The Rand Corporation, June 1974, 54 pp.

Genensky, S. M., Petersen, H. E., Yoshimura, R. I., von der Lieth, J. B., Clewett, R. W., & Moshin, H. L. *An interactive CCTV system for educating partially sighted and some other types of handicapped children.* The Rand Corporation, March 1974, 36 pp.

Gill, J. M., & James, G. A. Mobility maps: The choice of symbols. *The New Beacon* (Royal National Institute for the Blind, London), February 1974, 58 (682), 35-38.

Presentation of a set of mobility map symbols adopted after extensive evaluation for touch discrmination and ease of interpretation.

Gill, J. M., & Tobin, M. J. *European register of research on visual impairment.* Coventry, England: Department of Engineering, University of Warwick, May 1974.

Greenberg, G. L., & Sherman, J. C. Design of maps for partially seeing children. In *International Yearbook.* Gutersloh, West Germany: Kartographisches Institut Bertelsmann, 1970, 111-115.

Handikappinstitutet. *Report on European conference on technical aids for the visually handicapped, March 1974.* Bromma 1, Sweden: Handikappinstitutet, June 1974. 302 pp.

Hermelin, B. Locating events in space and time: Experiments with autistic, blind, and deaf children. *Journal of Autism and Childhood Schizophrenia,* 1972, 2(3), 288-298.

Hermelin, B., & O'Connor, N. Spatial coding in normal, autistic and blind children. *Perceptual and Motor Skills*, 1971, 33, 127-132.

Hermelin, B., & O'Connor, N. Right and left handed reading of braille. *Nature*, June 18, 1971, 231(5303), 470.

Huggins, A. W. F. More temporally segmented speech: Is duration or speech content the critical variable in its loss of intelligibility? *Quarterly Progress Report* No. 114, Research Laboratory of Electronics, MIT, 185-193.

Hviid, J. *Ikke-handicappedes reaktioner over for handicappede.* (The reaction of the non-handicapped towards the handicapped.) Denmark: Gylendal, 1972. 335 pp.

This study is based on interviews with handicapped and non-handicapped persons to explore emotional and psychological reactions of the non-handicapped toward physical disfigurement. An extensive bibliography follows the text on pages 302 to 307; an English summary appears on pages 323 to 332.

ICTA Information Center. *Disabilities and housing requirements.* Bromma 3, Sweden: ICTA Information Centre, September 1974. (Disabilities include: Allergy, Cystic fibrosis; Epilepsy; Extremely short stature; Impaired hearing and deafness; Impaired function of the kidneys; Impaired sight; Psoriasis; Retarded mental development; Motor disabilities; and Enterostomy operations.)

Jackson, John S. (Ed.) *Proceedings of the 1973 Carnahan conference on electronic prosthetics.* Lexington, Ky.: Office of Research & Engineering Services, College of Engineering, University of Kentucky, November 1973. 133 pp.

Jacobs, K. Sehbehinderte auf dem Weg zum Beruf: Probleme und Entwicklungstendenzen. (The visually impaired in search of a profession: Problems and developing trends.) *Sehgeschardigte*, Internationales Wissenschaftliches Archiv, No. 3 (November 1973), S. 64-95.

James, G., & Armstrong, J. An evaluation of the Silva braille compass: 1 - Static tests. *The New Beacon*, September 1974, 58(689), 225-229.

James, G., Campbell, D., & Armstrong, J. An evaluation of the Silva braille compass: 2 - Field trials. *The New Beacon*, October 1974, 58(690), 253-255.

James, G., Armstrong, J., & Campbell, D. Verbal instructions used by mobility teachers to give navigational directions to their clients. *The New Beacon*, April 1973, LVII(672), 86-91.

Jensen, O., & Truelsen, H. T. *Maend Med Synshandicap*. (People with sensory handicaps.) Denmark: Mentalhygiejnisk Forskningsinstitut, 1973. (Danish with English summary.)

Kafafian, H. *Study of man-machine communications systems for the handicapped.* (Second Report, Volumes I and II, prepared for the U.S. Office of Education, Bureau of Education for the Handicapped, Project No. 18-2003.) Washington, D.C.: Cybernetics Research Institute, February 19, 1970. 92 pp.

Kafafian, H. *Study of man-machine communications systems for the handicapped.* (Final Report, Volume III, prepared for the U.S. Office of Education, Bureau of Education for the Handicapped, Project No. 18-2003 and No. 7-0533) Washington, D.C.: Cybernetics Research Institute, 1973. 266 pp.

Kakalik, J. S., Brewer, G. D., Dougharty, L. A., Fleischauer, P. D., Genensky, S. M., & Wallen, L. M. *Improving services to handicapped children*. (R-1420-HEW) Santa Monica, California: Rand, May 1974.

Brewer, G. D., & Kakalik, J. S. *Improving services to handicapped children: Summary and recommendations*. (R-1420/1-HEW) Santa Monica, California: Rand, May 1974.

Kay, L. Orientation for blind persons: Clear path indicator or environmental sensor. *The New Outlook*, September 1974, 68(7), 289-296.

Kirman, J. H. Tactile perception of computer-derived formant patterns from voiced speech. *Journal of the Acoustical Society of America*, January 1974, 55(1), 163-169.

Lassen, P. *Barrier free design: A selected bibliography*. Washington, D.C.: Paralyzed Veterans of America, Inc., 1974. 103 pp.

Contains references under 22 headings, including standards and specifications, human factors, planning, housing, transportation, and bathrooms and kitchens.

Mehr, E. B., Frost, A. B., & Apple, L. E. Experience with closed circuit television in the blind rehabilitation program of the Veterans Administration. *American Journal of Optometry*, June 1973, 50(6), 458-469. (*Bulletin of Prosthetics Research*, Spring 1974, 10(21), 54-68.)

Miller, D., Zuckerman, J. L., & Reynolds, G. O. Holographic filter to negate the effect of cataract. *Arch. Ophthalmology*, October 1973, 90, 323-326.

National Academy of Sciences. *A preliminary evaluation of the Bionic Instruments--Veterans Administration C-4 Laser Cane*. Washington, D.C.: Advisory Panel for the Evaluation of the Laser Cane, Subcommittee on Sensory Aids of the Committee on Prosthetics Research and Development, Division of Medical Sciences, National Research Council, National Academy of Sciences, September 1973. 211 pp.

Nelson, J., & De l'Aune, W. A quantitative assessment of blinded veterans' comprehension of discrete time compressed speech. *IRCS* (Research on: Biomedical Technology; Eye; Psychology; Social and Occupational Medicine), 1974, 2, 1440.

Newland, T. E. Le test d'aptitude a l'apprentissage pour aveugles (BLAT). (Manual: The blind aptitude learning test.) *Bulletin de Psychologie*, 1973-1974, XXVII(310), (5-9), 398-402. Test manual and embossed material available from T. Ernest Newland, 703 South Race Street, Urbana, Illinois.

Nizetic. B. Prevention of blindness: Potentialities of a systems analysis approach. *Acta Ophthalmologica*, 1974, Vol. 5, 134-144.

Noll, A. M. Man-machine tactile communication. *SID Journal*, July/ August 1972.

Copies of this paper are available upon request to IRIS.

O'Connor, N., & Hermelin, B. M. The reordering of three-term series problems by blind and sighted children. *Br. Journal of Psychology*, 1972, 63(3), 381-386.

O'Connor, N., & Hermelin, B. Seeing and hearing and space and time. *Perception & Psychophysics*, 1972, 11(1A), 46-48.

Office of Demographic Studies. *Additional handicapping conditions among hearing impaired students: United States 1971-72*. Data from the annual survey of hearing impaired children and youth, Series D, Number 14. Washington, D.C.: Gallaudet College, November 1973. 49 pp.

Oomen, H. A. P. C. Vitamin A deficiency, xerophthalmia and blindness. *Nutrition Reviews*, June 1974, 32(6), 161-166.

Otto, W. (Ed.). Research in reading: As reviewed in *The Journal of Educational Research 1933-1973*. Special issue. *The Journal of Educational Research*, May-June 1974, 67(9), 386-420.

Pastalan, L. A. The simulation of age-related sensory losses: A new approach to the study of environmental barriers. *The New Outlook*, October 1974, 68(8), 356-362.

Rodabaugh, B. J., Weisgerber, R. A. *Optacon: Ink print reading for the blind*. Palo Alto, Calif.: American Institute for Research, September 1974. 44 pp.

The American Institutes for Research study summarized in this booklet has been more fully described in a final report submitted to the Bureau of Education for the Handicapped, U.S. Office of Education, Washington, D.C. Organizations and individuals interested in obtaining a copy of this report are referred to the: ERIC Document Reproduction Service, P.O.B. 90, Arlington, Virginia 22100.

Rowell, D. The binaural sensory aid for the blind. In the Proceedings of the Conference on Engineering Devices in Rehabilitation, Boston, May 2-3, 1974. Cambridge, Mass.: Massachusetts Institute of Engineering. 37-41.

Rowell, D. Auditory factors in the design of a binaural sensory aid for the blind. In the proceedings of the 4th Annual Meeting, Biomedical Engineering Society, Los Angeles, California, January 29-30, 1974.

Rowell, D., Lawrence, P. D., & Perron, A. G. Volitional control for a scanning sensory aid for the blind. In the Proceedings of the Conference on Engineering Devices in Rehabilitation, Boston, May 2-3, 1974. Cambridge, Mass.: Massachusetts Institute of Engineering. 42-45.

Sachs, R. M. Technology comes to telecommunications for the hearing impaired. *Highlights*, 52(3), Fall 1973, 16-18.

Smith, G. C., & Mauch, H. A. Abstract of summary report on the development of a reading machine for the blind (July 1973). *Bulletin of Prosthetics Research*, BPR 10-20, Fall 1973, 231-232.

Spahr, J., & Fankhauser, F. On automation of perimetry--problems and solutions. Switzerland: Universitats-Augenklinik Bern.

Summary: After a brief description of the components of the Octopus, an automated perimeter, two mathematical strategies, leading to correct threshold determination are compared. The efficiency of finding the true threshold value is evaluated by means of computer simulations. An artificial patient being represented by subprograms which simulate variable threshold fluctuations and variable degrees of reliability. It is shown that the efficiency measured in percentage of correct answers obtained is best for one specific

type of strategy, when a large range of misjudgments or uncertainties of the true threshold is assumed.

Suen, C. Y., & Beddoes, M. P. Development of a digital spelled-speech reading machine for the blind. In IEEE Transactions on Biomedical Engineering, Vol. BME-20, No. 6, November 1973, 452-459.

Tobin, M. J., & Hunter, B. Assessing the manual dexterity of the visually handicapped. *The New Beacon*, 56(687), 169-172.

Veringa, F. Non-adequate stimulation as a tool in visual physiology. *Archives Internationales de Physiologie et de Biochimie*, 1974, 82(2), 361-363.

Vinding, J. *Braille printing program system description.* Denmark: Dansk Blindesamfund, Computerized Braille Production, 1974. (Unpublished report.)

Wilber, L. A. Acoustic impedance evaluation. *Highlights*, Fall 1973, 52(3), 4-6.

Abstracts prepared by the Educational University of Heidelberg, Department for Education of Blind and Partially Sighted (Teacher College and Research Center).

Copies of the studies, in German, are available from the Institut fur Blinden-und Sehbehindertenpadagogik, 69 Heidelberg, Ziegelhauser Landstrasse 35, West Germany. DM o, 15 per page.

Bossert, A. The educational system for the visually handicapped in Denmark. 187 pp.

In the context of several earlier studies on the educational facilities of foreign countries, this paper describes the situation in Denmark intensively. In this country there has been an immense change in the organization of the educational system for the blind and partially sighted during the past ten years.

The description is based on an analysis of papers on special education, legal texts, educational trips, interviews, and correspondence. The educational system for the blind and partially sighted is discussed in connection with special education in general as well as the regular school system.

Haas, P. Physical education at schools for the partially sighted in the Federal Republic of Germany. 175 pp.

The first part of this paper deals with the results of questionnaires, assessing the situation of physical education at schools for the partially sighted. More than 1000 questionnaires had been sent to teachers and students (grades 5-9). Some of the results are the following: The preferred kind of sport is swimming, followed by soccer. Sixty-one percent of the students would like to have more sport; 93 percent of the teachers feel that advanced training for teachers is necessary. Twenty-four percent are specially trained teachers; only 10 percent of the teachers instructing in sport are specially trained in sport and education of the partially sighted.

In the second part a skiing course with 13 partially sighted students is described.

Krug, F. & R. Physical aptitude of partially sighted children. 198 pp.

Physical carriage, organic efficiency and motor coordination was tested in 43 partially sighted children aged 7-8 years, with a control group of normally seeing children, matched according to age, place of residence (rural/urban), sex, and socioeconomic status of parents. The results indicated that the partially sighted more often have a poor carriage (not significant), to have less efficient organs (significant), and have significantly lower scores in their coordinative performance.

Schiller, H., & Siebertz, M. Social background of the students in schools for the blind and partially sighted. 132 pp.

The social status of 869 students of schools for the blind and 1713 students of schools for the partially sighted has been classified according

to the device of Kleining and Moore. Results show that 66 percent of the students of schools for the blind and 70 percent of those at schools for the partially sighted belong to lower social classes. These classes are significantly overrepresented among the visually handicapped students in special school settings compared to the normal population in the GFR (45 percent). This effect is not due to the additionally mentally retarded children.

Possible reasons and consequences of this result are discussed.

Schleehauf, U. Adventitiously visually handicapped professional workers. 82 pp.

Written biographic materials by the author analyzed the problems of 14 visually handicapped adults working on academic level.

The description is concerned with the individual anamnesis, visual handicap, direct consequences, search for new possibilities, new beginning, rehabilitation, new profession, review.

After an introducing discussion of the methodologic problems and the description of the procedure to obtain the material, the case studies are reported in detail.

The results justify the method fully. The paper gives a good accounting of the problems of these persons and raises various questions for further research.

Thumm, I. Parents of partially sighted children: Statements on the possibilities of their children at school, occupation, and social contacts. 175 pp.

The parents of 15 students of a school for the partially sighted were interviewed concerning their opinion on special education of partially sighted children, occupational possibilities and social integration. The interviews are reported in detail. The summary shows that the parents are well aware of the advantage and disadvantage of special schools. The later occupational situation of their children, however, can't be judged by the parents in a realistic manner. Psychological problems of the children stemming from their impairment is mostly denied whereas all children have very few contacts to normally seeing peers.

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